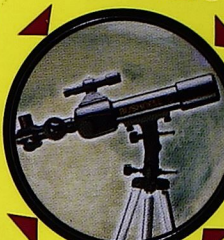




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Over 500 asteroids have been found with orbits that cross the Earth's, but over 300 of these have been "lost" since they were first seen.

CHANCES ARE...
The chance of being killed by an asteroid is about one in 5,000, greater than that of being killed in a plane crash. But this is because an asteroid strike could kill millions, whereas in a plane crash, the numbers are small. No one has been hit in 1,000 years.

More people work in a single McDonald's restaurant than are employed worldwide to monitor asteroids.

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Data

MOON FACTS & FIGURES

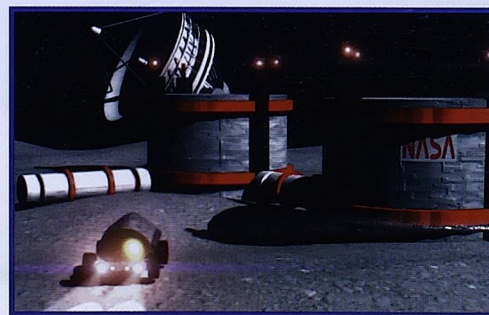


DIAMETER	2,160 MILES
AXIS TILT	6° 41' RELATIVE TO ITS ORBIT
TIME TO ORBIT EARTH	27.3 EARTH DAYS
LENGTH OF DAY	27.3 EARTH DAYS
DISTANCE FROM EARTH	238,850 MILES
SURFACE TEMPERATURE	253°F (DAY) TO -387°F (NIGHT)
SURFACE GRAVITY	0.17 OF THE EARTH'S
MASS	0.012 OF THE EARTH
VOLUME	0.02 OF THE EARTH
DENSITY	3.34 TIMES THAT OF EARTH

FUTU
What if...

...WE RETURNED TO THE MOON?

Twelve American astronauts landed on the Moon between 1968 and 1972 during the Apollo program. No one has been back since. NASA has plans to send astronauts back to the satellite before the end of the century. Administrator Daniel Goldin has also outlined plans for a lunar base that may be launched from the Moon. Analysis of the rocks brought back by the Apollo astronauts show that the Moon contains useful amounts of metals, such as aluminum, iron, titanium and magnesium, which could be used to build spacecraft. And since the Moon's gravity is weaker than the Earth's, launching rockets from there would be far easier.



Plans for building a Moon base are already well advanced, though no date has been set. Ultimately, there will be mining colonies on the surface supplying Earth with minerals (above).

...WE ESTABLISHED A MOON BASE?

The discovery of water ice at the Moon's poles has stimulated plans to set up bases using pressurized cylinders, like those used in present-day space stations. The cylinders will be covered with lunar soil to protect them from cosmic rays and meteorites.

At first, scientists will use the bases to explore the mountains, craters and valleys of the Moon to find out more about its history. Observatories will be established to obtain a clearer view of the sky than is possible from Earth, where our atmosphere gets in the way. It will also be desirable to set up radio telescopes, to study the cosmos free of interference from radio transmissions on Earth.

Energy to power the lunar bases will come from sunlight. Solar power will also be used to convert the water ice at the poles into

hydrogen and oxygen for fuel; oxygen for breathing will be extracted from the deposits currently "locked away" as oxides in the Moon's rocks. The same rocks could be used to extend the bases. Plants for food will be grown in Moon soil, with added water and fertilizer; farm animals and fish will be kept in pressurized domes.

Eventually, we will mine the Moon for the valuable minerals that it contains. Instead of rockets, magnetic ramps called mass drivers may be used to propel containers of Moon rocks into space. The rocks will then be ferried to Earth or processed in space factories. One day it may also be possible for tourists to take vacations on the Moon, living in lunar hotels and visiting sites such as Tranquillity Base, where the first Apollo astronauts landed in 1969.

KILLER ASTEROIDS

CLASSIFICATION EARTH-CROSSING ASTEROIDS



Earth-crossing asteroids—lumps of stray matter whose orbits cross that of the Earth—are not just the invention of disaster movies: Asteroid strikes are a real possibility, and have actually happened in the past. The chances of a collision in our lifetime are small. But if an asteroid were to hit us, there is a strong possibility that it would occur without warning. And if the asteroid were large enough, it could cause enough damage to signal the end of life on Earth as we know it.

SEE ALSO ASTEROID BELT, COMETS, METEORITES



Factoids

LOST IN SPACE

Over 500 asteroids have been found with orbits that cross the Earth's, but over 300 of these have been "lost" since they were first seen.

CHANCES ARE...

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BIG MISTAKE?

More people work in a single McDonald's restaurant than are employed worldwide to monitor asteroids.

Data ASTEROID FACTS

CLOSEST RECORDED APPROACHES

Name	Date	Closest to Earth
1994 XL1 (FORMERLY XM1)	Dec 9, 1994	65,000 MILES
1993 KA2	May 20, 1993	93,000 MILES
1991 BA	Jan 18, 1991	93,000 MILES
4581 ASCLEPIUS	Mar 1, 1989	372,000 MILES
HERMES	Oct 30, 1937*	558,000 MILES

* Has since disappeared—the only named asteroid to be officially "lost" in space

LARGEST KNOWN ASTEROIDS

Name	Astronomical Number	Diameter
CERES	1	590 MILES
VESTA	4	360 MILES
PALLAS	2	330 MILES
HYGEIA	10	269 MILES
DAVIDA	511	240 MILES

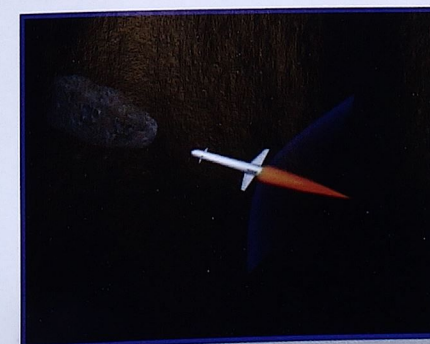
FUTURES What if...

...WE COLLIDED WITH AN EARTH-CROSSER?

Imagine a large asteroid was on a collision course for Earth. How much notice would we get? Duncan Steele is an astronomer who has been trying to alert the world's governments to the danger: "If a half-mile asteroid hits us, we can expect six seconds' warning. When it hits, the sky will light up like a thousand suns. By the time you've turned to look at it, it will have struck the ground, releasing energy equivalent to 10,000 times the Hiroshima bomb. Then it's goodbye."

Although asteroids this size are known to exist, most are only spotted when they are close to Earth, and on their way past us. Our closest known encounter so far was with 1994 XL1, which was located only 14 hours before its nearest approach. It was 100,000 times fainter than can be seen with the naked eye, and was about 30 feet across. Scientists have since worked out that 1994 XL1 missed us by just 52 minutes.

The discoverer of 1994 XL1, Jim Scotti, said afterward: "While I did find this little guy, I missed the 40 or 50 objects of similar size that passed within the Moon's distance that day."



OPTION 1
Firing a nuclear missile at the body risks exposing the Earth to the debris. Detonation near the asteroid, to shatter it, is a safer bet.

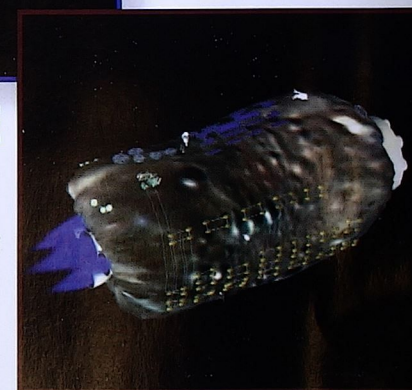


OPTIONS 2 & 3
Diverting the body from its course could be achieved by rocket boosters or by making it a self-powered "spaceship."

...WE HAD SOME WARNING?

Even if we had warning of an Earth-crosser, what could we do? Small ones could be blown up with missiles, but with larger objects, there is still a risk from the debris. A better plan would be to alter the asteroid's orbit. John Dale Solem of Los Alamos National Laboratory has worked out that exploding a nuclear bomb in front of the oncoming body would be enough to nudge it off course without shattering it—but we would need at least five months' warning.

Another option would be to land rocket boosters on the asteroid to blast it off-course. Far into the future, we might even be able to make icy comets self-propelling by melting their ice core with nuclear power so that the resulting steam acted like a giant rocket.



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DOOMSDAY STRIKE

Every night, thousands of shooting stars appear in the night sky, evidence of the huge quantity of space matter that is constantly bombarding the Earth's atmosphere. Most of these objects are small meteors that burn up harmlessly before they reach the surface. However, out in space there are some very large objects, some a mile or two across. And between the small rocks and the really large ones lie many more, too small to spot, yet big enough to cause considerable damage if they hit the Earth.

Such impacts have occurred in uninhabited areas several times this century. Scientists are warning that it is only a matter of time before there is a major disaster.

LOCAL DAMAGE

SIZE OF BODY

Up to 200 yd in diameter

RATE OF IMPACT

One to 10 per century

IMPACT OVER LAND

May explode in the air, causing a multi-megaton blast that flattens the area below for hundreds of miles. Could cause extensive local damage, but no lasting environmental effects.

IMPACT OVER SEA

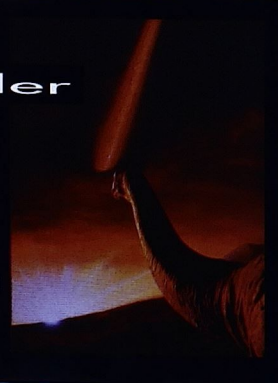
If it does not break up and is close to shore, could cause a small tsunami (tidal wave) with localized flooding. If in deep ocean, probably no effects.



TRUE STORY

Dinosaur Killer

A 110-MILE WIDE UNDERSEA CRATER OFF THE COAST OF YUCATAN, MEXICO, MAY EXPLAIN THE EXTINCTION OF THE DINOSAURS 65 MILLION YEARS AGO. SOME SCIENTISTS THINK THAT THE CRATER WAS CAUSED BY A 10-MILE-WIDE ASTEROID. DUST AND SMOKE FROM THE EXPLOSION WOULD HAVE BLOTTED OUT THE SUN FOR YEARS, KILLING OFF MUCH OF THE EARTH'S VEGETATION, AND INTERRUPTING THE FOOD CHAIN ON WHICH THE DINOSAURS DEPENDED.



WIDESPREAD DEVASTATION

SIZE OF BODY

200 yd to 1 mile in diameter

RATE OF IMPACT

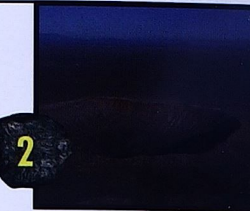
One every 10,000–1 million years

IMPACT OVER LAND

Could blast a crater up to 10 miles wide, with devastation on a national scale around the area of impact. Worldwide environmental effects (for example, loss of a season's crops), resulting in large-scale famine, collapse of the world's financial markets, and serious economic depression.

IMPACT OVER SEA

A worldwide tsunami that could flood all land below 200 ft above sea level (including New York, Washington and most of Holland).



"IMPACT" WINTER

SIZE OF BODY

1–10 miles in diameter

RATE OF IMPACT

One every 1–100 million years

IMPACT OVER LAND

A crater up to 100 miles across. Dust cloud from impact would contaminate atmosphere, resulting in a "nuclear winter" that could last for several years. Major famine and economic crises in both rich and poor countries—even those far from blast.

IMPACT OVER SEA

A giant tsunami, with catastrophic effects on most coastlines. Low-lying nations across the globe virtually wiped out.



TRUE STORY

Siberian Blast

THE BIGGEST IMPACT FOR 100 YEARS TOOK PLACE IN SIBERIA, RUSSIA ON JUNE 30, 1908. WHILE STILL FOUR MILES FROM THE GROUND, THE OBJECT SHATTERED WITH A FORCE AROUND 2,000 TIMES THAT OF AN ATOM BOMB AND FLATTENED THOUSANDS OF SQUARE MILES OF FOREST. THE ASTEROID WAS PROBABLY A 100,000-TON ROCK THE SIZE OF A LARGE HOUSE. THIS PHOTOGRAPH SHOWS SCIENTISTS LOOKING FOR PIECES OF THE DEBRIS. THE ARROW INDICATES A 660-LB FRAGMENT.



DOOMSDAY

SIZE OF BODY

Over 10 miles in diameter

RATE OF IMPACT

Fewer than one every 100 million years

IMPACT OVER LAND OR SEA

Loss of most life forms on Earth as a result of prolonged "impact winter" and consequent ice age.



Close Shave

Asteroids exist mostly in orbit around the Sun between Mars and Jupiter, in a vast ring known as the Asteroid Belt. Occasionally, though, an asteroid will leave its secluded orbit, and veer off into the inner solar system. This sudden change may be caused by an impact with another asteroid, or by the gravitational pulls of Jupiter or Mars.

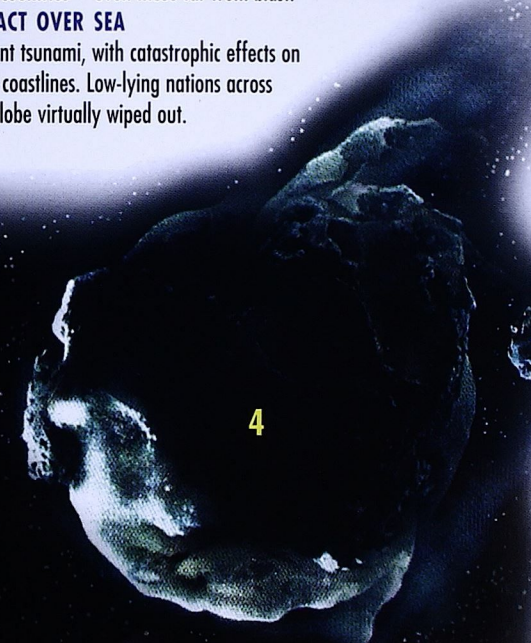
In recent years, astronomers have chanced on rocks a few hundred yards in diameter hurtling near to Earth. The closest near-collision so far was in 1994, when the body now known as 1994 XL1 came within 65,000 miles of us—four times closer than the Moon.

Each year, other asteroids are spotted coming almost as close, and it seems that the harder astronomers look, the more they find. It is now estimated that there are over 1,000 near-Earth asteroids roughly a mile in size. And although there is no known body due to hit the Earth, there are many asteroids out there that we don't know about.

Perhaps it is time to put more effort into searching for Earth-crossers. One may not strike for a thousand years, or it may hit us tomorrow.

FOUR STEPS TO DOOMSDAY

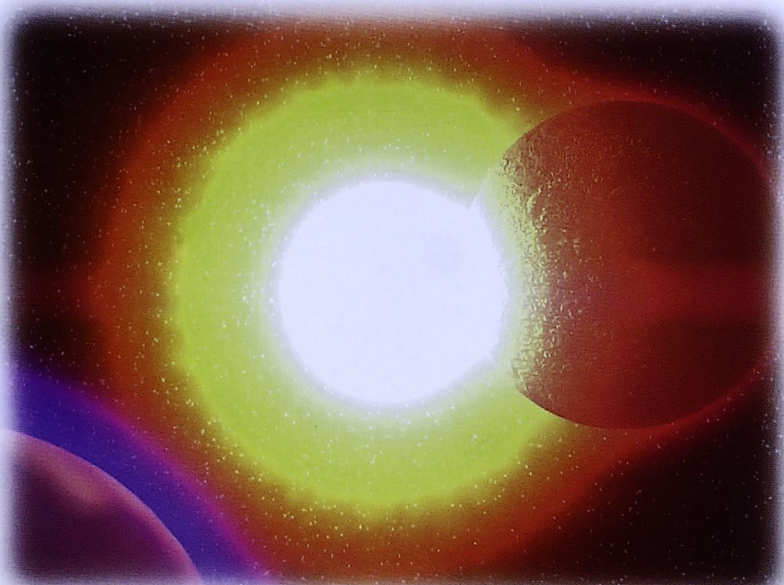
The Earth is continually bombarded by fragments of rock from outer space. The dangerous ones are those that are too small to spot until they are very close, yet large enough to cause widespread devastation.



CATEGORY 5 INTO THE UNKNOWN

SEEKING PLANETS

CLASSIFICATION PLANETS OF OTHER STARS



Are we alone in the universe, or are there other planets like the Earth circling other stars like the Sun? Until recently, astronomers knew of the nine planets in our solar system but could only speculate as to whether other stars had similar planets. But in the last few years, new observing techniques have confirmed the existence of so-called "extrasolar" planets. Soon, we may be able to start looking for signs of life on these new worlds, situated many light-years from the Earth.

SEE ALSO PLANETARY ORBITS, THE SOLAR SYSTEM



Factoids

SNIFFING LIFE

If aliens were looking for life on Earth, one clue would be the unusually large amount of methane in our atmosphere—most of it given off by termites and cows!

HOT TIP

In 1995 astronomers discovered the first planet orbiting a Sun-like star, 51 Pegasi. But it is an unlikely home for aliens: Its surface temperature is around 2,000°F.

SSSH...

Finding planets has been compared with seeking a lightning bug on a searchlight 1,000 miles away, or hearing a pin drop at a rock concert!

Data A DOZEN NEW PLANETS

From observations, astronomers can only work out the minimum mass of a planet as it orbits another star—so these planets could be much bigger.

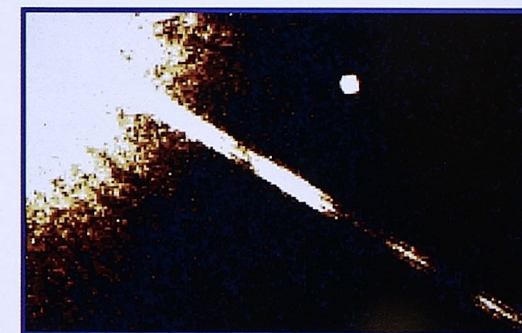
PARENT STAR	MINIMUM MASS (EARTH MASSES)	ORBITAL PERIOD (DAYS)	DISTANCE FROM STAR (COMPARED WITH EARTH'S DISTANCE FROM SUN)
PSR 1257+12	0.015	25.3	0.19
PSR 1257+12	3.4	66.5	0.36
PSR 1257+12	2.8	98.2	0.47
HD 114762	2,900	83.9	0.38
70 VIRGINIS	2,100	116.7	0.47
51 PEGASI	160	4.2	0.05
55 CANCRI	270	14.6	0.11
TAU BOOTIS	1,230	3.3	0.05
UPSILON ANDROMEDAE	220	4.6	0.06
RHO CORONAE BOREALIS	350	39.6	0.23
47 URSAE MAJORIS	730	1,108	2.1
16 CYGNI B	480	801	1.7

FUTURES What if...

...WE COULD FIND PLANETS SIMILAR TO EARTH?

Although life could take many forms, scientists believe that life-forms based on complex carbon-based molecules (as are human beings) are the most likely to exist elsewhere in the universe. They argue that we should look for planets that can support creatures like those on Earth—in other words, where surface water exists in its liquid form.

With this in mind, astronomers can calculate the distance from a star that would produce a temperature range narrow enough to sustain life. They call this the "habitable zone." The mass of the planet is also important. A planet much smaller than the Earth would quickly lose its atmosphere, while a more massive planet would retain a dense atmosphere of hydrogen. So far, all the planets found around Sun-like stars are far larger than Earth and most are closer to the parent star. They are likely to be gas giants, like Jupiter, rather than rocky bodies similar to the Earth. Some of the bigger ones may even be "brown dwarfs"—tiny stars that glow only dimly. But in the next few years, technological advances will allow us to detect smaller planets located much farther from their parent stars.



The Hubble Space Telescope easily picked out this "brown dwarf," Gliese 229b. But soon we will be able to spot actual planets that are likely to be habitable.

...THERE WAS LIFE ON THEM?

Assuming we found an Earth-size planet in a star's habitable zone, how would we check for signs of life? One way would be to train a radio telescope on the planet to listen for radio or TV signals, but we could easily miss creatures that did not possess the technology.

If we could actually see the planet, we could analyze its light spectrum, enabling scientists to identify the molecules in its atmosphere. Unique in our solar system, the Earth's atmosphere contains large amounts of oxygen, put there by plants. Signs of ozone (a form of oxygen), together with carbon dioxide, water vapor and methane, would be strong indicators that the planet was inhabited. NASA's Michael S. Kaplan says: "In 15 years we may have detected oxygen and water in the atmospheres of several planets within 10 or 20 parsecs." (One parsec is 3.26 light-years or 19 million million miles, 200 times the distance of the Earth's orbit around the Sun.)

Meanwhile, Roger Angel and Neville Woolf of the Steward Observatory at the University of Arizona have proposed a new kind of space interferometer—a device for analyzing light spectra. This would block out light from the parent star, revealing any planets in orbit around it—and also any traces of life.

STRANGE NEW WORLDS

Even the nearest stars to the Earth are so far away that it is impossible to detect planets in orbit around them. And even if we had a telescope large enough to see that far, such planets would be so close to their parent star that they would be swamped by the brilliance of the star itself, which would be at least a billion times brighter.

To get around these problems, astronomers have to search for planets indirectly. One method is to monitor the motion of the parent star very closely, checking to see if there are any irregularities that might be caused by the gravitational pull of orbiting planets. Unfortunately, such observations are difficult to make and even harder to

TRUE STORY

Breath of Life

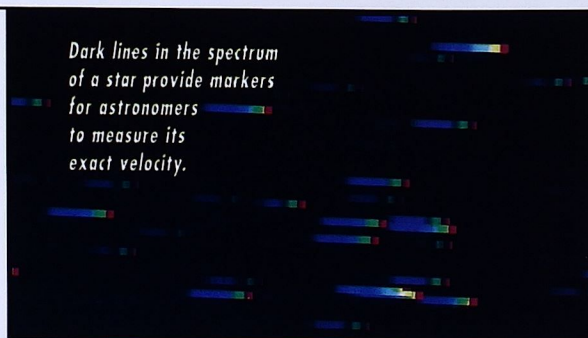
BECAUSE OF THE WAY OXYGEN READILY COMBINES WITH OTHER ELEMENTS, SCIENTISTS THINK THAT THE ONLY WAY FREE OXYGEN CAN EXIST IN AN ATMOSPHERE ALONG WITH OTHER GASES IS IF IT IS "BREATHED" OUT BY PLANTS. SO WHEN WE FINALLY GET TO ANALYZE GASES ON OTHER PLANETS, THE FIRST TEST WILL BE FOR THE PRESENCE OF OXYGEN.



SEARCHING SPECTRUMS

Any movement of a star causes the wavelengths of its light spectrum to shift: They shorten if the star moves toward an observer and lengthen if it moves away. By measuring the amount of this shift, astronomers can observe if a star moves along their line of sight and infer the existence of planets; but this is still like searching for a needle in a haystack. The gravitational pull of the giant planet Jupiter causes the Sun to move slightly. But for a distant observer to see this movement, they would have to detect shifts in the wavelengths of the Sun's spectrum of one part in 25 million over a period of 12 years!

Dark lines in the spectrum of a star provide markers for astronomers to measure its exact velocity.



SEEING FARTHER THAN EVER BEFORE

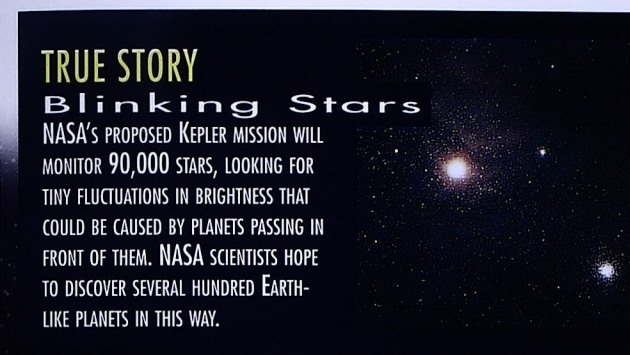


Distant star

TRUE STORY

Blinking Stars

NASA'S PROPOSED KEPLER MISSION WILL MONITOR 90,000 STARS, LOOKING FOR TINY FLUCTUATIONS IN BRIGHTNESS THAT COULD BE CAUSED BY PLANETS PASSING IN FRONT OF THEM. NASA SCIENTISTS HOPE TO DISCOVER SEVERAL HUNDRED EARTH-LIKE PLANETS IN THIS WAY.



Taking the Pulse

The first extrasolar planets were found to be orbiting a *pulsar*—the remains of an exploded star which emits pulses of radio waves. By studying small changes in the pulses from pulsar PSR 1257+12, scientists have inferred that there are three planets orbiting it.

Although researchers claim to have found over a dozen new planets, not all astronomers are convinced. Some argue that pulse-rates are affected by streams of gas emitted by our Sun. Others say that the changes are caused by the slow rise and fall of a star's surface rather than by planets orbiting around it. Such doubts may not be settled until a new generation of space telescopes—like the Darwin Project—is devised to obtain direct images of extrasolar planets.

Light emitted by star

Positional rockets

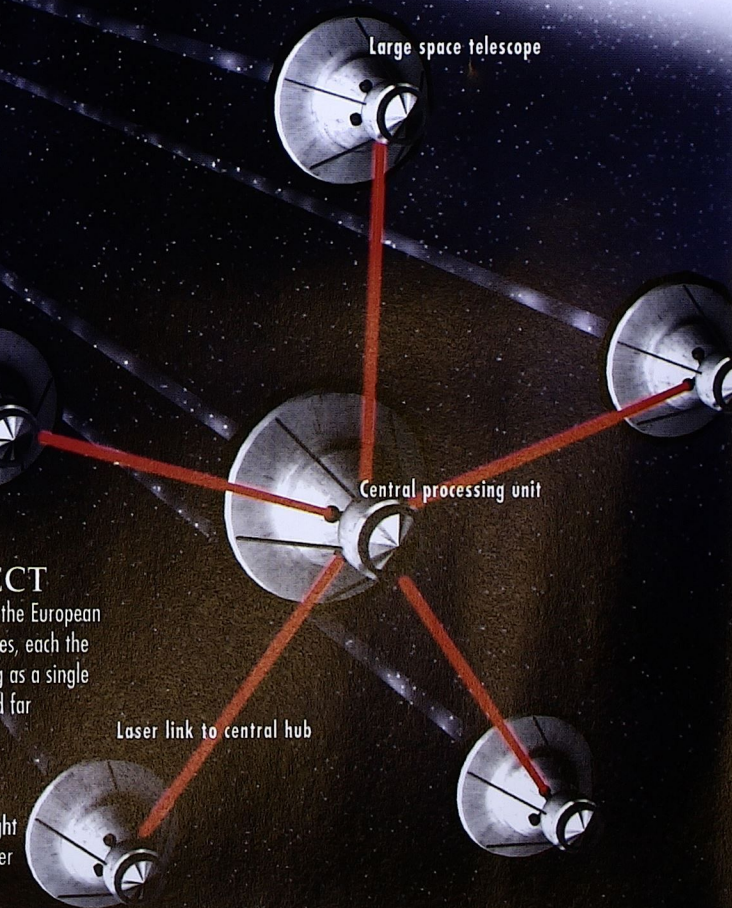
Large space telescope

Central processing unit

Laser link to central hub

THE DARWIN PROJECT

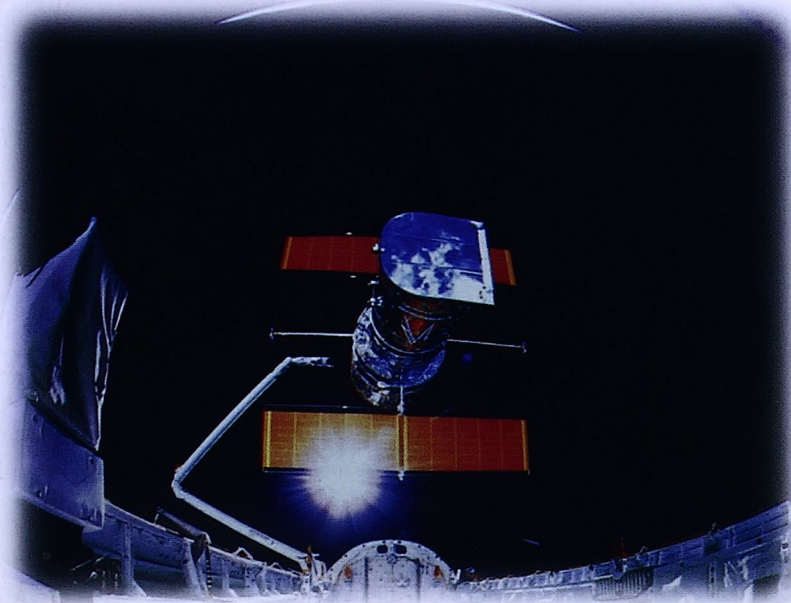
The Darwin Project, a study undertaken by the European Space Agency, envisages six linked telescopes, each the size of the Hubble Space Telescope, working as a single giant telescope 100 yards across. Positioned far out in space between Mars and Jupiter, this huge instrument would be able to image Earth-sized planets accompanying the 300 nearest Sun-like stars. It will analyze the light reflected from such planets to reveal whether they possess the conditions for life.



CATEGORY 4 MISSION LOG

HUBBLE TELESCOPE

CLASSIFICATION GIANT EYE IN THE SKY



In 1990, the Hubble Space Telescope (HST) was carried into Earth orbit by the Space Shuttle *Discovery*. Its 15-year mission was to take a closer look at our solar system, the Milky Way and other galaxies and to gaze back in time into the farthest reaches of the universe. Although there are larger telescopes based on Earth, the HST has the benefit of being above the atmosphere, enabling it to give us a much clearer view of the heavens—the pictures it has sent back have been truly stunning.

SEE ALSO SEEKING PLANETS, GIANT TELESCOPES



Factoids

FIRST THOUGHTS

In 1923, the German rocket science pioneer Hermann Oberth suggested mounting a space telescope on a crewed space station, built on an asteroid!

HST'S MENTOR

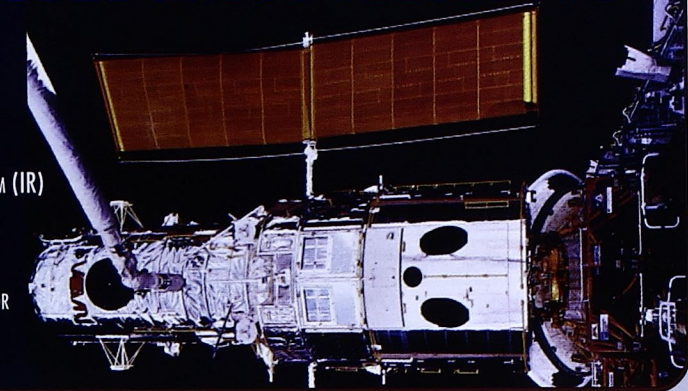
Astronomer Lyman Spitzer developed the basic idea for the HST, leading to the launch of two small space observatories in the 1960s. He also chaired the committee responsible for its creation.

SPLIT HAIRS

The cause of Hubble's early problems was a mirror flattening 0.0001 of an inch: one-fiftieth the width of a human hair.

Data HUBBLE SPACE TELESCOPE

MASS	11.4 TONS
LENGTH	43 FT
DIAMETER	14 FT
PRIMARY MIRROR	8 FT
SECONDARY MIRROR	1 FT
WAVELENGTH RANGE	110 NANOMETERS (UV) TO 1 MM (IR)
ANGULAR RESOLUTION	0.1 ARC-SEC
POINTING ACCURACY	0.007 ARC-SEC FOR 24 HR
MAGNITUDE RANGE	5 TO 29
ORBIT	380 MILES AT 28.5° TO EQUATOR
ORBITAL PERIOD	94 MIN
PLANNED LIFETIME	15 YR



FUTURES What if...

...THE HUBBLE'S MISSION IS EXTENDED?

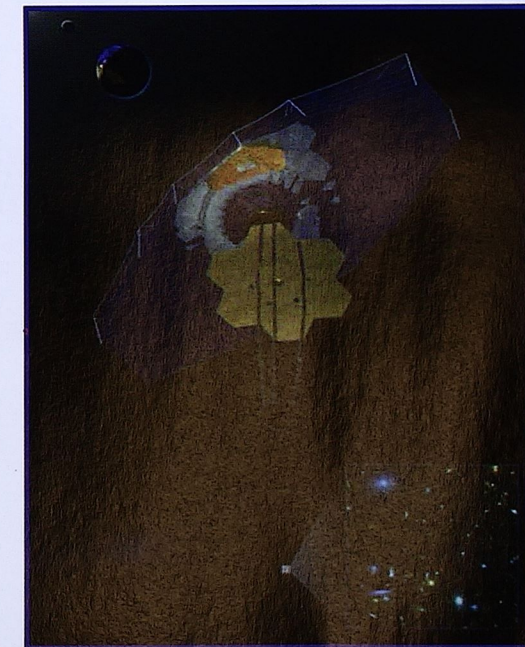
In 2002, the Advanced Camera (AC) will replace the Hubble's Faint Object Camera (FOC). The AC will use the latest digital technology to give a wider field of vision than the FOC. It is designed to study the atmospheres of the planets, the evolution of galaxies, and the mysterious "dark matter" that is thought to make up most of the universe. The AC is built to last beyond the Hubble's planned lifetime. This has led to speculation that the Hubble might continue in operation after 2005, though according to Carolyn Collins Petersen and John Brandt of the University of Colorado, tight budgets at NASA could be an obstacle. The European Space Agency, which gets 15% use of the Hubble until 2002 as a result of its contribution to the original costs, might be asked to contribute again.

...THE HUBBLE WAS REPLACED?

Scientists and engineers are already hard at work on a replacement for the Hubble Space Telescope, known as the Next Generation Space Telescope (NGST). The idea is to site NGST at the point where the pull of gravity from the Earth and the Sun cancel each other out—some 1 million miles out in space toward the Sun.

The NGST will be three times bigger, yet four times lighter, than Hubble. It will be cheaper, too, with a planned budget of just \$500 million. Three designs are currently on the drawing board, each of which features an ultra-lightweight mirror up to 26 feet across and weighing under 16 pounds. The mirror will be a carbon composite rather than glass.

The new telescope will be launched using a conventional uncrewed rocket, with the mirror folded up inside the nose-cone (the way the mirror unfolds is the major difference between the three designs). One advantage of putting the telescope far out in space is that it will not heat up and cool down as it goes in and out of the Earth's shadow, as the HST does. The drawback is that it cannot be repaired if anything goes wrong. With luck, the NGST will be able to see galaxies forming at the very edge of the universe, and to look for life on planets orbiting other stars.



A million miles closer to the Sun, the NGST will have problems keeping cool. Along with the folding mirror, it will have to deploy an umbrella to shade its sensitive instruments.

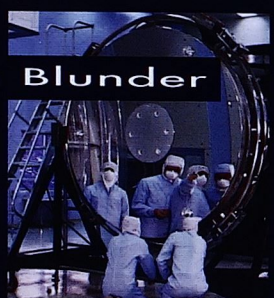
WINDOW ON THE UNIVERSE

No matter how big you build an Earth-based telescope, it has one great drawback: the atmosphere absorbs and deflects incoming light, thereby degrading the view. The solution—putting a telescope into orbit—only became feasible with the development of the Space Shuttle, due to the size and sensitivity of the equipment involved. Even so, plans for a Large Space Telescope or LST (named Hubble in 1983) were already well under way by the time of the launch of the first shuttle, *Columbia*, in 1981.

TRUE STORY

\$1.6 Billion Blunder

THE HUBBLE'S MAIN MIRROR WAS GROUND FROM A \$1 MILLION BLANK BY THE U.S. COMPANY PERKIN ELMER, ONE OF WHOSE INSTRUMENTS WAS CALIBRATED WRONG. THE MISTAKE SHOULD HAVE BEEN PICKED UP BY A PRE-LAUNCH CHECK, BUT PERKIN ELMER WAS UNDER PRESSURE TO DELIVER ON TIME AND ON BUDGET, SO IT WAS NOT SPOTTED UNTIL THE HUBBLE WAS IN ORBIT. DUBBED "THE \$1.6 BILLION BLUNDER" BY THE MEDIA, THE FAULT WAS EVENTUALLY CORRECTED DURING A SPACEWALK BY REPLACING ONE OF THE HUBBLE'S INSTRUMENTS WITH A REFOCUSING UNIT. THE REPAIR AND SERVICING MISSION COST \$800 MILLION.



COMET WATCH

Although Hubble's pictures of other planets in the solar system cannot compare with those taken by fly-by space probes, it does allow for regular and long-term observation. A prime example of the Hubble's value came when it showed the comet Shoemaker-Levy 9 crashing into Jupiter (right).



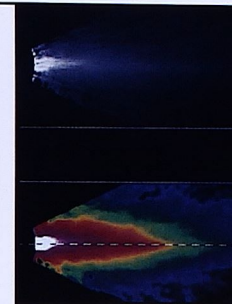
HOW BIG?

The Hubble can see out toward the farthest reaches of the universe, helping us to estimate how big it is, and also how old it is. Data from Hubble has helped scientists confirm that the universe will continue to expand instead of collapse back in a "Big Crunch."



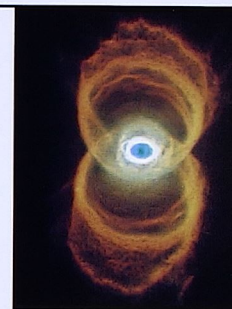
LIFE SEARCH

The Hubble allows us to search for planets orbiting other stars, which no ground-based telescope can see. Where there are planets, there may also be life. Here, Hubble shows a new solar system beginning to form around the star Beta Pictoris.



STAR DEATH

The Hubble has brought us this spectacular picture of the Hourglass Nebula. The nebula is made up of the remnants of a dead star, puffed into space at the end of the star's life. By analyzing images like these, scientists gain new insights into the life cycle and evolution of stars.



Ground Control

The Hubble is roughly the size of a railroad car and is built to fit inside the Shuttle's cargo bay. It occupies a low Earth orbit, circling at an altitude of just 320 miles, and is controlled from the ground. Attached to its "eyepiece" are two cameras—one that looks in great detail at a small area of space, and one that focuses on much larger areas or objects. Other instruments analyze the infrared waveband and characteristics of light.

Data from Hubble is relayed to White Sands, New Mexico, then on to mission control at the Goddard Space Flight Center near Washington, D.C. Another link forwards the data to the Space Telescope Science Institute in Baltimore. The HST costs an estimated \$8 a second to use. Excluding the cost of shuttle launches, \$4 billion will be spent on the Hubble in its lifetime.

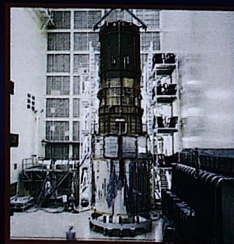


Mission Diary

HUBBLE SPACE TELESCOPE

1977 Hubble Space Telescope project approved. Budget estimated at \$450 million—85% to come from NASA and the rest from the European Space Agency. Launch date is set for 1983.

1979 Construction of Hubble begins. Launch is rescheduled for 1986.



1986 Launch of Hubble is postponed by the *Challenger* Shuttle disaster. By now costs have soared to \$1.6 billion—three times the original budget.

APRIL 24, 1990 Hubble is finally launched into space in the cargo bay of shuttle *Discovery*.

APRIL 24, 1990 Hubble is deployed in low Earth orbit.

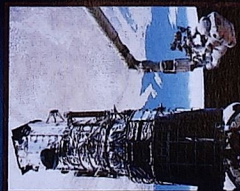


MAY 20, 1990 The space telescope's "first light"—Hubble is turned toward the star cluster NGC 3532, but the image is out of focus, rendering the HST little better than Earth-based telescopes.

DECEMBER 5-9, 1993

Astronauts from the Shuttle *Endeavour* make the longest U.S. spacewalk to date: 29 hr, 40 min.

DECEMBER 18, 1993 Repairs proclaimed a success.



FEBRUARY 19, 1997 A second service mission adds two new instruments and effects running repairs.

1999 Third service mission scheduled to install Advanced Camera.

2002 Fourth scheduled service mission: Hubble's instruments to be replaced and updated.

2005 Hubble's mission scheduled to come to an end.



BLACK HOLES

CLASSIFICATION SEARCHING IN THE DARK



A black hole is an object whose gravitational pull is so great that nothing—not even light—can escape from it. At one time, black holes were entirely theoretical. But now their existence, both in our own galaxy and elsewhere in the universe, has been confirmed. A black hole forms when a massive star dies and collapses under its own mass. Some black holes, billions of times more massive than the Sun, lie at the centers of distant galaxies. Others may have been forged in the first fiery moments of the universe.

SEE ALSO SUPERNOVA, RELATIVITY, WORMHOLES



Factoids

DARK STARS

Black hole theory is far from new. The idea began in 1783 when the Rev. John Michell used Newton's theory of gravity to predict the possibility of "dark stars."

NAME CHANGE

In 1915, Einstein's Theory of Relativity predicted so-called "Schwarzschild singularities." They were renamed "black holes" in 1967.

COSMIC VACUUM

Black holes have a reputation for sucking in everything around them. But they are no more deadly than any other object of the same mass—if you keep your distance.

Data BLACK HOLES LARGE & SMALL

OBJECT	MASS	RADIUS OF EVENT HORIZON
V404 CYGNI	12 SUN MASSES (24,000 TRILLION TRILLION TONS)	24 MILES
CYGNUS X-1	20 SUN MASSES (40,000 TRILLION TRILLION TONS)	40 MILES
CENTER OF MILKY WAY	1 MILLION SUN MASSES (2 BILLION TRILLION TRILLION TONS)	2 MILLION MILES (ABOUT 10 LIGHT-SECONDS)
CENTER OF M 106	36 MILLION SUN MASSES (72 BILLION TRILLION TRILLION TONS)	72 MILLION MILES (THE RADIUS OF VENUS' ORBIT OF THE SUN)
CENTER OF M 87	3 BILLION SUN MASSES (6 TRILLION TRILLION TRILLION TONS)	6 BILLION MILES (60 TIMES THE RADIUS OF THE EARTH'S ORBIT OF THE SUN)
MINI BLACK HOLE*	ABOUT 100 MILLION TONS	THE SIZE OF AN ATOMIC NUCLEUS
...and if our Earth and Sun were black holes, how big would they be?		
OBJECT	MASS	RADIUS OF EVENT HORIZON
THE EARTH	7 BILLION TRILLION TONS	ABOUT A THIRD OF AN INCH
OUR SUN	300,000 EARTH MASSES (2,000 TRILLION TRILLION TONS)	2 MILES

* existence not proved

FUTURES What if...

...WE COULD HARNESS THE ENERGY OF A BLACK HOLE?

Far from consigning great tracts of the universe to oblivion, black holes could actually be beneficial. The mathematician Roger Penrose of Oxford University, England, has calculated that a technologically advanced civilization could extract enough energy from a black hole to supply all of its power requirements.

Penrose's idea requires the civilization to build a structure encircling the black hole, from which a stream of fuel can be "fed" into it. At the event horizon, each particle in the fuel stream is then split into two fragments—perhaps using suitably placed explosive charges. Penrose has calculated that at the very moment one of these fragments falls over the black hole's event horizon, the other fragment will throw out a kick of pure energy supplied by the annihilation of its partner. This is something like the boost you get after jumping from a carousel.

The theory goes on to suggest that the "energy kicks" could be collected by the structure around the black hole; but energy extracted in this way would not be limitless. Calculations by Demetrios Christodoulou—a researcher at Princeton University, New Jersey—show that a black hole's rate of spin is steadily reduced by the Penrose process. There comes a point when the black hole stops spinning, and its energy-producing properties vanish.

If the same civilization could build a craft capable of withstanding the enormous forces that apply in and around a black hole, scientists have speculated that it might be possible to cross the event horizon into a new region of space-time through what is known as a *wormhole*. So living next to a black hole could not only save on utilities—it could also provide the ultimate travel ticket to the rest of the universe, past, present and future.



An advanced civilization could power itself by exploiting the energy locked away in a rotating black hole.

...WE WERE THREATENED BY A BLACK HOLE?

Thankfully, the black holes we know about are no danger to Earth, since only objects within a black hole's event horizon can actually be sucked into it. The closest stellar-sized black hole to the Earth is at least 15 light-years away, and supermassive black holes are confined to the centers of distant galaxies, so they pose no conceivable threat.

It has been suggested that there may be "mini black holes," formed shortly after the Big Bang, still scattered about our galaxy. But as yet, none have been found; they remain purely theoretical.

INTO THE HEART OF DARKNESS

Throw a ball into the air and gravity will bring it back down to Earth. But throw the ball fast enough—around 25,000 mph—and it will escape from the Earth's gravity into space. More massive objects than the Earth have stronger gravitational fields that demand higher escape velocities (EVs); the Sun's EV, for example, is about 100 times the Earth's.

Black holes are bodies so massive and dense that their theoretical EV is greater than the speed of light itself. This means that not even light can escape from such bodies, rendering them effectively invisible—hence the name.

A black hole is formed when a very large star—at least 30 times the mass of the Sun—dies and collapses under its own weight. It shrinks down to an infinitely dense point known as a *singularity*, at which point conventional mathematics can no longer cope. Around the singularity is an imaginary circle

TRUE STORY

Limited Life

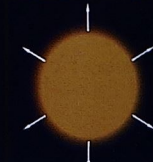
BLACK HOLES ARE NOT COMPLETELY BLACK. ENGLISH PHYSICIST STEPHEN HAWKING (RIGHT) HAS SHOWN THAT BLACK HOLES GIVE OFF FAINT RADIATION, WHICH IMPLIES THAT EVENTUALLY THEIR MASS MUST EVAPORATE IN A HAZE OF SUBATOMIC PARTICLES.



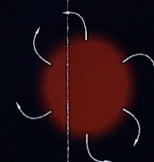
called the *event horizon*, beyond which all light from the object is turned back by the force of its own gravity. And since Einstein proved that gravity can not only capture light, but can also distort time and space, inside the event horizon the entire concept of space and time completely breaks down.

You could never see a person actually fall into a black hole: as they approached the event horizon, time would slow to the point where it would take infinitely long to reach it! In the meantime, the black hole's gravitational pull on light would make them appear to fade away. As for the person, who knows? All we know for sure is that in a black hole, reality as we know it ceases to exist.

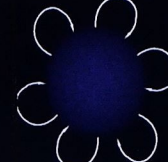
HOW STARS BECOME BLACK HOLES



REGULAR STAR
Shines due to light radiated from core.



SUPERDENSE BODY
Dying star's gravity pulls light back.



BLACK HOLE
Core is so dense, light can no longer escape.

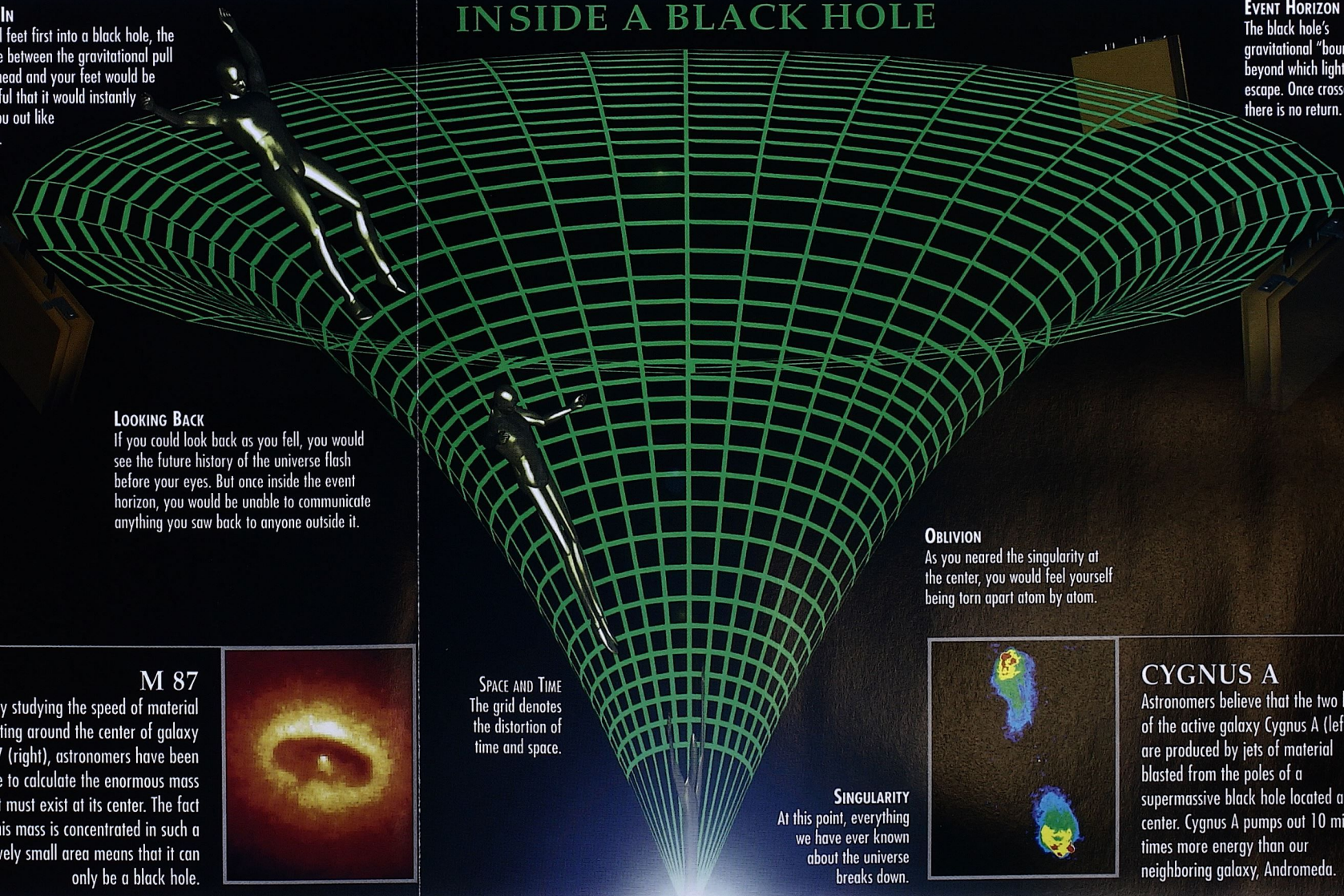
STELLAR HOLES

Many black holes have similar masses to regular stars. They are too dark to be seen directly, but astronomers infer their presence by monitoring their gravitational effects on nearby bright stars. Sometimes, a black hole's gravitational pull "captures" material from a companion star (right). This material becomes agitated and heats up, causing it to emit X-rays that astronomers can also detect. So far, the best candidate for a stellar-mass black hole is V404 Cygni, discovered in 1989.



FALLING IN

If you fell first into a black hole, the difference between the gravitational pull on your head and your feet would be so powerful that it would instantly stretch you out like spaghetti.



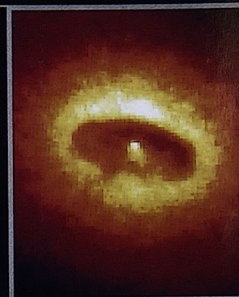
INSIDE A BLACK HOLE

LOOKING BACK

If you could look back as you fell, you would see the future history of the universe flash before your eyes. But once inside the event horizon, you would be unable to communicate anything you saw back to anyone outside it.

M 87

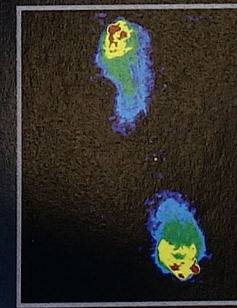
By studying the speed of material rotating around the center of galaxy M 87 (right), astronomers have been able to calculate the enormous mass that must exist at its center. The fact that this mass is concentrated in such a relatively small area means that it can only be a black hole.



SPACE AND TIME
The grid denotes the distortion of time and space.

OBLIVION

As you neared the singularity at the center, you would feel yourself being torn apart atom by atom.



CYGNUS A

Astronomers believe that the two lobes of the active galaxy Cygnus A (left) are produced by jets of material blasted from the poles of a supermassive black hole located at its center. Cygnus A pumps out 10 million times more energy than our neighboring galaxy, Andromeda.

SINGULARITY
At this point, everything we have ever known about the universe breaks down.

CATEGORY 7 SPACE TECHNOLOGY

CAPE CANAVERAL

CLASSIFICATION NASA'S LAUNCH SITE



Cape Canaveral, Florida, is the world's most famous launch site. "The Cape," as it is known in the space business, along with the adjoining Kennedy Space Center (KSC), has seen more successful launches into orbit than any other U.S. site. In 1997, no fewer than eight crewed Space Shuttle flights blasted off from NASA's KSC, and another 15 crewless Delta, Atlas and Titan rockets took to the skies from the U.S. Air Force's Cape Canaveral launchpads, located a few miles to the south.

SEE ALSO INTERNATIONAL LAUNCH SITES



Factoids

RAINING INSIDE

The Cape's Vehicle Assembly Building was made to house up to four Saturn 5 rockets. It is so tall that clouds formed on the ceiling until air conditioners were installed.

MIGHTY MOVER

The Crawler that carries the Space Shuttle to its pad is the world's heaviest and slowest vehicle. Crawler and Shuttle together weigh 10 million pounds.

DREAM ON

The Cape's Visitor Center exhibits full-size rockets and spacecraft, plus IMAX movies like *The Dream Is Alive*.

Data CANAVERAL COUNTDOWN

LAUNCHES SINCE 1958	MORE THAN 500
CREWED LAUNCHES TO END OF 1997	118
SPACE SHUTTLE LAUNCHES TO END OF 1997	88 (INCLUDING ONE FAILURE)
SHUTTLES LANDING AT KSC TO END OF 1997	41 (THE REST LANDED AT EDWARDS AIR FORCE BASE IN CALIFORNIA)
FIRST U.S. CREWED LAUNCH	MAY 5, 1961 FROM PAD 5
FIRST CREWED MOON LANDING LAUNCH	APOLLO 11 FROM PAD 39A
FIRST SPACE SHUTTLE LAUNCH	APRIL 12, 1981 FROM PAD 39A
WORST LAUNCHPAD DISASTERS	APOLLO 1 FROM PAD 34 IN 1967 SHUTTLE CHALLENGER FROM PAD 39B IN 1986

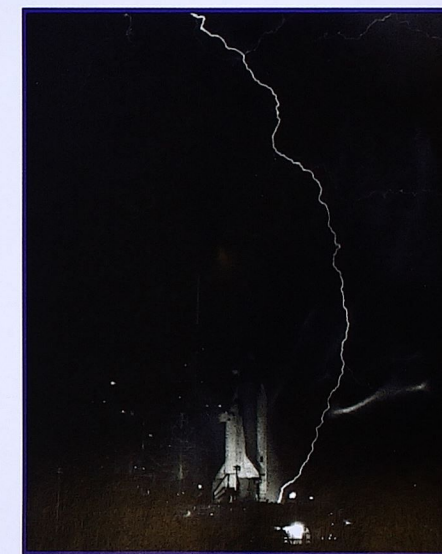
FUTURES

What if...

...NASA CHOSE ANOTHER LAUNCH SITE?

Although Cape Canaveral has been a thriving launch site for some 40 years, it is not without its problems. The weather—especially thunderstorms—can delay launches, and occasionally results in launch emergencies. Apollo 12 was hit by lightning in November 1969, but still made it to the Moon. An Atlas Centaur was not so lucky when lightning struck in 1987—it exploded. And a sudden cold snap was later discovered to be a major contributing factor to the *Challenger* disaster of January 1986. Another problem is that the Cape can only support a launch from each operational pad every 30 days at best. Once a rocket is on the pad, the next booster is stuck in line. But if the first rocket is delayed for some reason, it is impossible to do a quick swap unless there are two launchpads equipped to handle the same booster. It is hard to see how this problem could be overcome wherever a new launch site was situated.

Lightning is a major problem at the Cape. This strike narrowly misses the ill-fated Shuttle Challenger only hours before blastoff.



...SITES LIKE CAPE CANAVERAL BECAME OBSOLETE?

Most rockets are by their nature expendable and are discarded after launch. Even the Space Shuttle is only partly reusable: It can land on a runway, but it still needs massive rocket boosters—and a launch site—to lift it into space. The huge waste involved has led to calls for the development of totally reusable systems which could ultimately take off and land from conventional runways. Such systems are already on the drawing board, but it is doubtful that they could ever make use of conventional airports or military air bases. A more likely scenario is that reusable systems will employ modified launchpads. This bodes well for the future of the Cape, although the existing facilities

will need substantial modification to handle more streamlined launch operations. In the short term, most of the work is likely to focus on faster processing of boosters in new buildings, and in greater automation of the launch preparations. The launchpads will remain basically the same. The Cape's new Pad 46 has been equipped to accommodate new types of reusable boosters and is the first of its kind to be built. But expendable-booster systems such as the new Delta 3 and 4 are likely to be launching satellites well into the 21st century. And they will be launched from the same pad—number 17—that saw the first attempt to reach the Moon with an crewless probe in 1958!

THE WORLD'S BUSIEST SPACEPORT

Cape Canaveral is a 15-mile-long sand spit that juts out from the east coast of Florida into the Atlantic Ocean. It is well placed, in that rockets can be launched over open sea rather than inhabited land, but it is by no means the perfect place to live and work. Once the home of Seminole Indians, the Cape area is a largely desolate expanse of sand, palmetto scrub and palm trees. The natural inhabitants include alligators, many species of birds and hordes of voracious mosquitoes. Together, they supply a somewhat strange backdrop to what is unquestionably the world's foremost center of

technological endeavor. The Cape proper is operated by the 45th Space Wing of the U.S. Air Force. Across the Banana River, on Merritt Island, is the adjoining NASA Kennedy Space Center (KSC). The whole area is a mass of sprawling launchpads, concrete roads, hangars and buildings.

NASA's Launch Complex 39, where there are two pads for the Space Shuttle, is at the northern tip of Merritt Island. Located south of the Shuttle

pads on the Cape proper are Pads 40 and 41, which are used by the U.S. Air Force to launch Titan 4 rockets. The Titan 4 is the largest uncrewed U.S. booster and is used mainly to carry spy satellites into orbit.

THE CRAWLER

The Crawler carries the fully assembled Space Shuttle and its mobile launch platform from the VAB to the launchpad. Moving at 1 mph, it takes 8 hours to make the 3-4 mile journey. The Crawler's four 41-ft-long twin caterpillar tracks run along a 7-ft-deep crack-proof double-gravel track. This system once moved the giant Saturn 5 rockets.



TRUE STORY

How It All Began

THE FIRST LAUNCH FROM THE CAPE (THEN KNOWN AS THE "LONG RANGE PROVING GROUND FOR MISSILE TESTING") TOOK PLACE ON JULY 24, 1950, WHEN A GERMAN V-2 MISSILE, ATTACHED TO A U.S. WAC-CORPORAL UPPER STAGE (RIGHT), FLEW TO AN ALTITUDE OF 10 MILES. AMERICA'S FIRST SATELLITE, EXPLORER 1, FLEW FROM LAUNCHPAD 26 ABOARD A V-2-DERIVED JUPITER C BOOSTER ON JANUARY 31, 1958.



high, its doors are the largest in the world. Nearby is the 3-mile-long Shuttle landing runway.

Beyond the many now inactive pads toward the south of the Cape is Complex 36, with two operational Atlas launchpads. These are primarily used for launching commercial communications satellites. Farther south, beyond the two commercial Delta booster launchpads at

Complex 17, is Port Canaveral.

The Port, too, is a hive of space activity; this is where Space Shuttle boosters recovered from the sea are landed to be readied for another launch. The Port is also a center for tourist cruises. Farther south still is Cocoa Beach, a brash "space town" where sunbathers get a grandstand view of blast-offs.

Vehicle Assembly Building

Both the Cape and KSC are hives of activity day and night. Spacecraft and boosters are constantly being assembled and launched from the 10 operational launchpads by a workforce of around 12,000 people. The Vehicle Assembly Building (VAB) on northern Merritt Island, where the shuttle is assembled, is 716 feet long, 518 feet wide and 525 feet high. At 460 feet

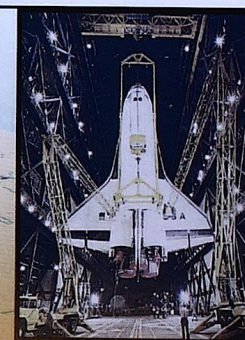
VISITING KSC

Visitors are welcome at the KSC. First stop is the new Apollo Saturn Center, where a Saturn 5 rocket is laid out on view. Visitors are then driven to within a few feet of the VAB and to a new observation building a mile from Pad 39A, where the Shuttle is launched. Another stop is the recently established International Space Station center.



THE VAB

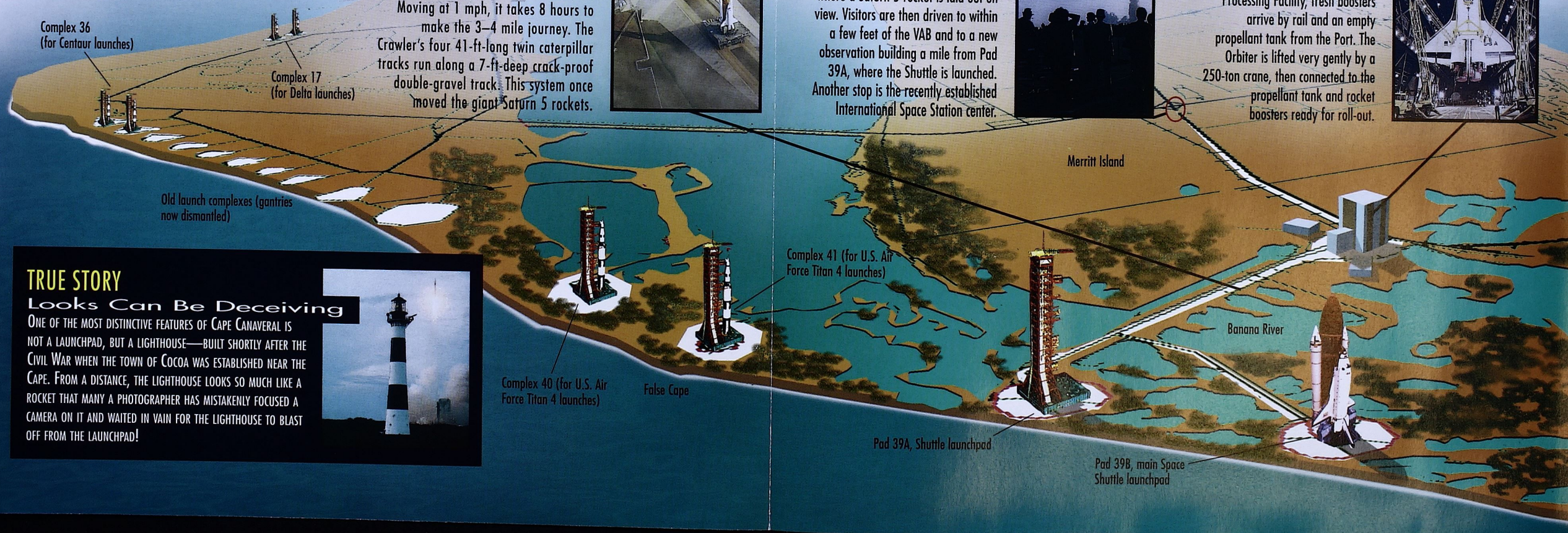
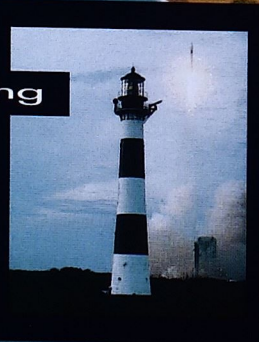
For final Space Shuttle assembly, the Orbiter is returned from the Orbiter Processing Facility, fresh boosters arrive by rail and an empty propellant tank from the Port. The Orbiter is lifted very gently by a 250-ton crane, then connected to the propellant tank and rocket boosters ready for roll-out.



TRUE STORY

Looks Can Be Deceiving

ONE OF THE MOST DISTINCTIVE FEATURES OF CAPE CANAVERAL IS NOT A LAUNCHPAD, BUT A LIGHTHOUSE—BUILT SHORTLY AFTER THE CIVIL WAR WHEN THE TOWN OF COCOA WAS ESTABLISHED NEAR THE CAPE. FROM A DISTANCE, THE LIGHTHOUSE LOOKS SO MUCH LIKE A ROCKET THAT MANY A PHOTOGRAPHER HAS MISTAKENLY FOCUSED A CAMERA ON IT AND WAITED IN VAIN FOR THE LIGHTHOUSE TO BLAST OFF FROM THE LAUNCHPAD!



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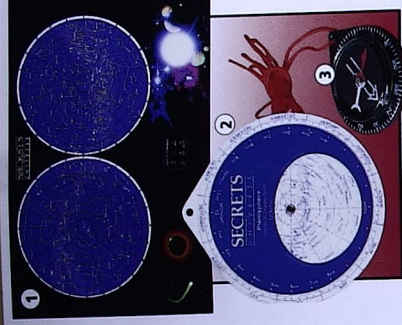
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*Price subject to change.

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Accepting your Free Gift Package will not obligate you in any way. A gift is a gift! You do not have to purchase any more cards. However, once you see how magnificent they are, I think you'll want to order more.

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Sincerely,

Steve Leonard

Steven Leonard

P.S. Return your Gift Claim Certificate within 10 days and get a fabulous Star-Gazing Kit — FREE! (Limit one per family please.)

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Journey To The Final Frontier

To introduce you to the fun and excitement of collecting SECRETS OF THE UNIVERSE cards, we have a bounty of free gifts waiting for you.

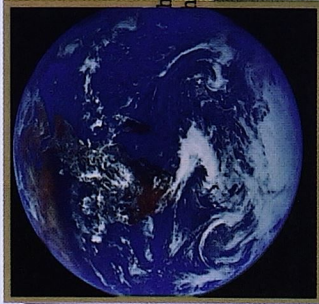
Have you been awarded our highest gift level?

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Good Luck!

**LIMIT ONE
PER HOUSEHOLD**

**LOOK WHERE YOUR
FREE GIFT PACKAGE
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Take a walk in space and view the planet earth as you've never seen it before — in it's majestic, natural beauty.



Blast off into space on the Space Shuttle Discovery. This launch signified the return to manned space flights since the 1986 Challenger tragedy.



Witness the birth of a star within the M16-Eagle Nebula. These eerie dark structures known as Pillars of Creation are actually columns of cool interstellar hydrogen gas and dust that are incubators for new stars.



Travel to the sixth planet from the sun — Saturn and its 18 confirmed moons. In the past, many proposed new moons have turned out to be just dense spots in Saturn's rings.

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FREE GIFT Your Free Gift Package could be worth as much as \$31.95! Find the enclosed Instant-Value-Game Pouch. Rip it open, take the Free Gift sticker from inside, and affix it here.

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Sticker Here
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SECRETS OF THE UNIVERSE GIVES AWAY OVER \$1,000,000 IN FREE GIFTS!

Stamford, CT. International Masters Publishers Inc. announced recently that it will be giving away over a million dollars worth of Free Gifts to space enthusiasts around the world. Invitations for the Free Gift Packages will arrive in the mail soon accompanied by a package of sample SECRETS OF THE UNIVERSE cards.

This consumer promotion campaign is designed to generate interest in the community for the mysteries of space. It did for Dennis Keller, of Colchester, CT. He had never had much interest in celestial phenomenon before he received a Free Gift Package from SECRETS OF THE

UNIVERSE in the mail. "I couldn't believe this company sent me so many wonderful gifts free. My kids and I really learned a lot about the universe and now we have a new hobby we enjoy together."

In a recent interview, the Director of SECRETS OF THE UNIVERSE said, "Our product gives people a fun, interesting, easy and inexpensive way to build the most beautiful and complete collection of SECRETS OF THE UNIVERSE cards anywhere. We believe that once people see this stunning new product for themselves, they'll want to own the whole collection." Of course, you may enter the new

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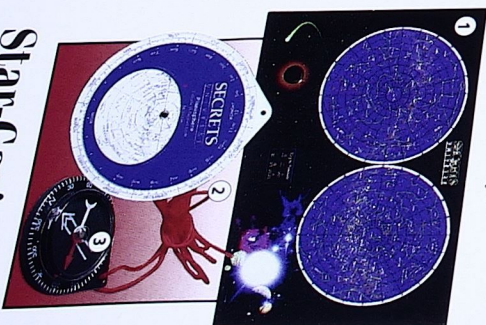
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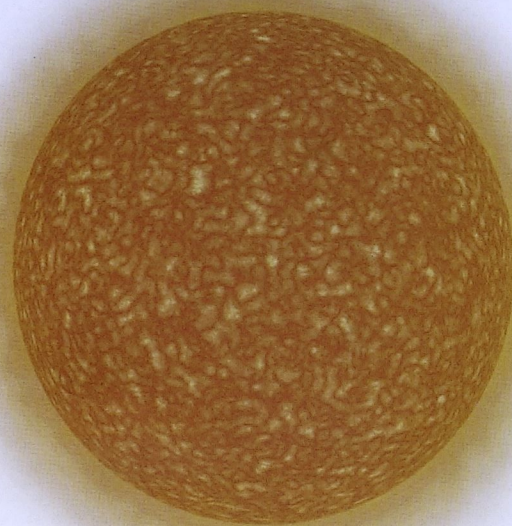
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CATEGORY 2 THE SOLAR SYSTEM

THE SUN

CLASSIFICATION INSIDE THE SOLAR FURNACE



The warmth that you feel on your skin on a sunny day originated in one of the most extreme environments in the entire universe—the nuclear cauldron that lies at the heart of a star. The star in question is the Sun, the body that supplies heat and light to the small planet we call Earth. The way the Sun generates energy in its fiery furnace, and the means by which that energy moves outward from the core to radiate as sunshine on the surface, are the keys to the evolution of life on this planet.

SEE ALSO OBSERVING THE SUN, SOLAR NEUTRINOS



Factoids

WARNING

Never look directly at the Sun with the naked eye or any optical device. The only safe way to observe the Sun is to project its image onto a piece of white paper using binoculars or a small telescope.

SLOW PROGRESS

It takes more than a million years for energy from the Sun's core to reach the surface, but from there it takes just 8 minutes for it to get to Earth.

WEIGHT LOSS

Nuclear reactions in the heart of the Sun turn 5 million tons of matter into energy each second. Even so, the Sun has another 5 billion years to live.

Data

SOLAR STATISTICS

AVERAGE DISTANCE FROM EARTH	92.957 MILLION MILES
DIAMETER	864,950 MILES
AGE	4.5 BILLION YEARS
MASS	1.99 MILLION, TRILLION, TRILLION TONS
AVERAGE DENSITY	1.4 TIMES THE DENSITY OF WATER
SURFACE TEMPERATURE	10,900°F
CORE TEMPERATURE	27 MILLION°F
COMPOSITION	AT LEAST 90% HYDROGEN, THE REST MOSTLY HELIUM WITH TRACES OF OTHER ELEMENTS

FUTURES

...THE SUN IS GETTING HOTTER?

Fortunately for life on Earth, the Sun's output of heat is remarkably consistent. But even a small change would have grave consequences, triggering either a new ice age, or runaway global warming. What evidence is there that this has happened in the past—or could happen in the future?

Scientists have been measuring the Sun's output for many years, initially from ground level, and now from space. Its level is almost constant, varying less than 1% over many years. But even a small change like this can have a marked effect on our climate. Between the 16th and 18th centuries the Earth was gripped by a "Little Ice Age." The climate became colder and caused rivers such as the Thames in London to freeze over in winter, allowing "frost fairs" to be held on the ice. Since then, the Thames has never frozen.

Looking farther into the past, studies of the fossilized remains of plants and animals suggest that the temperature on Earth has hardly varied. However, flare-ups in the Sun's output lasting only 200 or 300 years would not be expected to show up in the fossil records.

In 1972, Sun expert Douglas Gough of Cambridge University, England, worked out that the processes going on in the center of the Sun are, by their nature, unstable. Before this it had always been assumed that the Sun was reliably stable.

If Gough is right, the Sun could change in



Life on Earth relies on heat and light from the Sun. Once scientists believed that the Sun's energy output was constant. Now there are indications that it may be unstable, with potentially disastrous consequences for the Earth.

brightness by as much as 5% over a period of millions of years—a big change in astronomic terms. "The work created quite a stir," says Gough. "No one has yet been able to show that the idea is wrong, but people have rather been ignoring it in the hope that it will go away."

Now, other scientists are beginning to take more of an interest in Gough's work. Some believe that the global warming we are currently experiencing is not caused by greenhouse gases in the atmosphere, but by the Sun heating up.

It is true that the Sun will grow steadily hotter as it reaches the end of its life about 5 billion years from now, although the change will be so slight that it may be millions of years before we notice it. And by then, humans will probably possess the technology to roam the galaxy in search of new Suns to warm them.

THE SHINING

The Sun is made of gas, mainly hydrogen. But because this body of gas is so massive, the Sun's own gravity creates enormous heat (27 million°F) and pressure (500 billion pounds per square inch) at the core. Under these extraordinary conditions, the hydrogen atoms cannot exist in their usual form; they become stripped of their orbiting electrons, leaving just the naked nuclei, called *protons*.

The heat and pressure agitates these protons to a point where they continually collide with each other. This causes some pairs of hydrogen atoms to fuse together, creating a single atom of a new element—helium. Each time this happens, a minute amount of matter is converted into energy. For each ounce of matter that is annihilated, enough energy is produced to power a 100 W light bulb for about 750,000 years. And in the Sun, some 5 million tons of matter is annihilated every second.

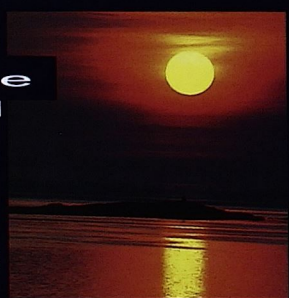
The energy released in these nuclear reactions heats up the core of the Sun still further, and produces high levels of radiation. *Photons*—tiny “packets” of this radiation—slowly make their way outward from the core through a superdense region called the *radiative zone*. After that, the photons reach the *convective zone* where the Sun is less dense and where giant pockets of super-hot gas bubble to the surface.

Eventually, the energy-carrying photons reach the surface and radiate out into space. Much of the energy takes the form of visible light, but in addition there is infrared light, x-rays and harmful ultraviolet rays. The

TRUE STORY

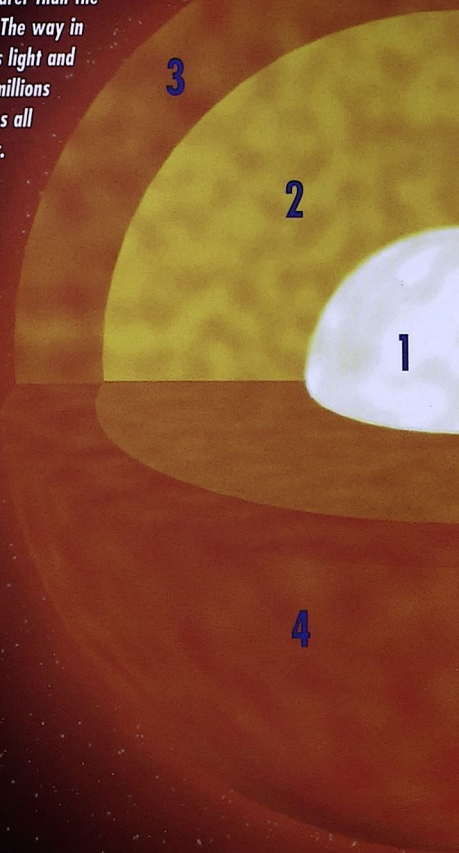
It's White

ALTHOUGH THE SUN APPEARS YELLOW WHEN SEEN FROM EARTH, IT IS ACTUALLY WHITE. WE SEE THE SUNLIGHT AFTER IT HAS BEEN FILTERED THROUGH THE EARTH'S ATMOSPHERE. AIR SCATTERS THE BLUE COMPONENT, MAKING THE SKY APPEAR BLUE AND THE SUNLIGHT YELLOW.



INSIDE THE SUN

The Sun is a star, just like the others that twinkle in the night sky. The Sun feels hot and dominates the sky because it is some 250,000 times nearer than the next closest star. The way in which it generates light and heat is a bit like millions of hydrogen bombs all going off together.



light comes from a region known as the *photosphere* which, effectively, is all we see of the Sun.

The photosphere appears grainy and is constantly moving. The grains seem to come and go, each one lasting some 25 minutes. These 600- to 1,000-mile-wide “granules” are actually the surface bubbling as energy is carried up from below. The surface of the Sun also shows a larger pattern, called *supergranulation*. Supergranules are each about 20,000 miles across, and are related to the massive convection bubbles in the convective zone below the photosphere.

Other Features

Above the photosphere is the *chromosphere*, which can be seen as a pink ring around the Sun during an eclipse. Above this is the *corona*, from which a hot, thin stream of particles—the *solar wind*—blows outward into space. Other visible features of the Sun include darker regions called *sunspots* and bright *flares*.

The internal workings of the Sun may be complex, but they are nevertheless crucial to our existence. Without them, we would have no light, no energy, and, of course, no life on Earth.

1 IN THE CORE



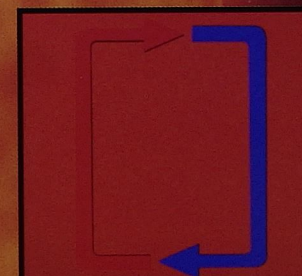
Pairs of hydrogen atoms combine to form helium atoms in a process known as *nuclear fusion*. During the process, matter is destroyed and energy given off. The amount of energy generated is given by Einstein's famous equation $E=mc^2$ (energy = mass x the speed of light x the speed of light). The numbers are enormous, as is the amount of energy generated!

2 RADIATIVE ZONE



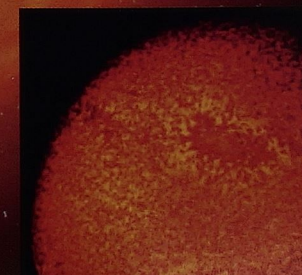
The matter near the center of the Sun is so densely packed that energy-carrying photons produced during the nuclear reactions have trouble finding their way through. They bounce from particle to particle in a so-called “random walk pattern” through the radiative zone. Their path is so slow that it can take over a million years for a photon to find its way out.

3 CONVECTION ZONE



Energy is carried from the radiative zone outward through the convective zone. Here, the hot gases boil up in giant convection cells rather like soup boiling in a pot—except that these “pots” are up to 20,000 miles across. The gases radiate the energy to the surface, then cool and sink down again, ready to pick up more energy.

4 PHOTOSPHERE



Here, smaller convection cells—up to 600 miles across—bubble up to the surface with more energy, giving the surface of the Sun a grainy appearance. The sunshine we see on Earth comes from the photosphere, which is the only part of the Sun we can see directly. The corona and flares are only visible during an eclipse.

TRUE STORY

Getting Together

SCIENTISTS HAVE CALCULATED THAT THE AVERAGE TIME ANY ONE PROTON IN THE SUN'S CORE WILL SPEND WAITING TO COLLIDE WITH ANOTHER PROTON IS GREATER THAN THE AGE OF THE UNIVERSE! EVEN SO, THERE ARE SO MANY PROTONS IN THE CORE OF THE SUN THAT THERE ARE COUNTLESS COLLISIONS EVERY SPLIT SECOND.



CATEGORY 3 UNDERSTANDING THE COSMOS

MILKY WAY

CLASSIFICATION GALAXY CONTAINING OUR SUN



Our Sun is only one of about 200 billion stars that, together with clouds of dust and gas, make up the Milky Way galaxy. Seen from Earth, the Milky Way appears as a misty band of light arched across the night sky. Closer inspection reveals star clusters, bright clouds, dark blotches and hazy glowing patches. In many mythologies, the Milky Way was said to be the road to heaven. We now know that it is simply our view of the vast pinwheel-shaped galaxy in which we live.

SEE ALSO SPIRAL GALAXIES, STAR CLUSTERS



Factoids

OUR GALAXY

Although the Milky Way takes its name from the band of stars we see across the sky, it also includes all stars visible to the eye.

NEIGHBORS

Around 2,500 stars are visible on a clear night, but this is just one 40-millionth of the total number of stars in the Milky Way. Most of the stars we can see are close neighbors.

BLACK HOLE

A hot fountain of gas that scientists have detected at the center of the Milky Way suggests that our galaxy may revolve around a black hole.

Data MILKY WAY FACTS

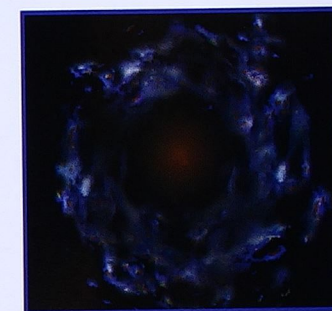
DIAMETER OF DISK	100,000 LIGHT-YEARS
THICKNESS OF DISK	2,000 LIGHT-YEARS
DISTANCE OF SUN FROM CENTER	25,000 LIGHT-YEARS
NUMBER OF STARS	AT LEAST 200 BILLION
TIME FOR SUN TO MAKE ONE CIRCUIT	200 MILLION YEARS

FUTURES

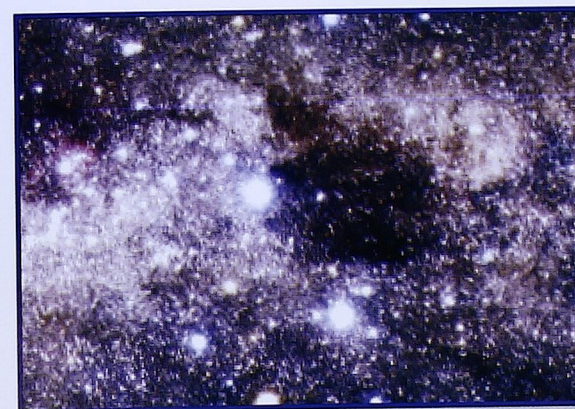
What if...

...OUR GALAXY DIED?

The Sun has made about 25 circuits of the galaxy since it first formed and will continue to do so for many billions of years to come. But the galaxy will not last forever. Although new stars are constantly being created among the gas clouds in the spiral arms, the supply of star-forming material is limited and will be exhausted in about 1,000 billion years. After then, no more stars will be made, and the existing stars will gradually fade away. The galaxy will begin to go dark, but the burned-out stars will continue to rotate around the heart (right).



...THE SUN PASSED THROUGH A DARK CLOUD?



Giant molecular clouds are another of the galactic dangers we face. If our solar system went through one, the resulting rain of comets could threaten our very existence.

comets in the solar system and could send many of them plummeting toward Earth. Earlier bombardment by comets may account for the extinction of prehistoric creatures like the dinosaurs. Some scientists have speculated that the solar system could "exchange" comets with such a cloud, and that our current collection of comets may have been acquired the last time the Sun passed near to one.

In the 1950s, the British astronomer Fred Hoyle wrote a science fiction story in which the Sun was enveloped in a dark cloud containing intelligent life. Later, the story inspired Hoyle and his colleague, Chandra Wickramasinghe, to suggest that life began within interstellar dust clouds and was brought to Earth by comets. The theory goes that the Earth is seeded with living organisms in "genetic storms" that occur every 100 million years or so as the Sun passes a giant molecular cloud. Although it is tantalizing, the idea is not widely accepted by other scientists.

ISLAND UNIVERSE

The Milky Way galaxy is similar in appearance to many other so-called "spiral galaxies." In the middle is the *bulge*, a lens-shaped region like the hub of a wheel about 15,000 light-years across. (A light-year is the distance light can travel in one year, about 6 trillion miles.) Rotating around the bulge is the flat, roughly circular *disk* of the galaxy, about 120,000 light-years across, but no more than 2,000 light-years thick. Within the disk are the *spiral arms*, marked by bright stars and by glowing clouds of gas and dust in which new stars are being formed. The Sun is located on the inner edge of the Orion arm, about halfway out from the center of the galaxy.

It is because we lie in the disk that we see the Milky Way as an encircling band of stars. The space between the stars is strewn with dust, which makes the stars look dimmer and redder than they really are. The dust also limits our view of the Milky Way to the stars in the neighboring spiral arms. To gaze deeper into the galaxy, astronomers must use radio and infrared waves, which can penetrate the dust.

Surrounding both the bulge and the disk is the *halo*, a roughly spherical region containing few stars but extending well beyond the edge of the disk. The most important objects in the halo are the *globular star clusters*, which move about the center in long, slow, elliptical orbits. About 150 are known.

TRUE STORY

Straight Spiral

How do we understand the structure of the Milky Way when we can never travel beyond it? The answer lies in the many other spiral galaxies that can be seen through powerful telescopes. After studying these galaxies, astronomers determined the spiral structure of the Milky Way by working out the distribution of bright stars, star clusters and nebulae. This map is made by analyzing radio waves emitted from clouds of hydrogen gas in the galaxy.



Our galaxy is one of about 100 billion galaxies, each one an island of stars in a dark and empty universe.

GLOBULAR CLUSTERS

Dense, ball-shaped swarms of several hundred thousand extremely old stars. Found mainly in the halo region.



OPEN CLUSTERS

Open clusters, like the well-known Pleiades, or Seven Sisters, are loose groupings of young stars that have formed relatively recently from clouds of interstellar dust and gas.



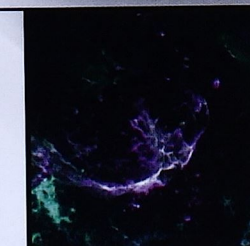
STAR NURSERIES

Complexes of dust and gas in which stars are being born. The newly formed stars light up the surrounding material, causing the region to glow.



SUPERNOVA REMNANT

The scattered debris of a once-massive star that has ended its days in an enormous explosion. Now known to be a powerful source of radio waves.



ANATOMY OF A GALAXY

THE HALO

The sparsely populated region extending above and beyond the spiral arms of the disk.

THE DISK

Flat and roughly circular, it contains most of the mass in the galaxy.

SPIRAL ARMS

Marked by young, recently formed stars.

NUCLEUS OF GALAXY

May contain a black hole a million times more massive than our Sun.

CENTRAL BULGE

A mass of stars, obscured from our view by clouds of galactic dust.

SAGITTARIUS ARM

Extends inward from the Orion arm.

PERSEUS ARM

Extends outward from the Orion arm.

THE SUN

Located on the inner edge of the Orion arm.

ORION ARM

The spiral arm containing our own Sun.

Young and Old

The stars in the Milky Way differ according to their location. The younger stars in the disk, known as Population I, are chemically distinct from the older, Population II stars in the bulge and halo. Astronomers interpret these differences to mean that the younger stars are made from recycled gas and dust that was once processed within earlier generations of stars.

The density of material in the galaxy tends to fall off away from the center: Stars are packed together closely in the bulge, but become more scattered out in the disk. At the heart of the galaxy, in the center of the bulge, is the enigmatic *nucleus*. This complex region, surrounded by swirling clouds of gas and dust, is a strong source of radio waves. Many astronomers think it contains a giant black hole.

CATEGORY 5 INTO THE UNKNOWN

TIME TRAVEL

CLASSIFICATION HOW TIME'S ARROW CAN BE REVERSED



Time travel is easy: All of us do it every day, but only in one direction. For thousands of years, scientists and philosophers have talked of time as a river that flows steadily onward year after year. But what if there were a way to swim against the flow, or to run down the bank ahead of the river? Might we be able to journey back and forth in time just as we travel through space? The idea is not as far-fetched as it sounds, and the implications for the future are intriguing.

SEE ALSO BLACK HOLES, PARADOXES OF RELATIVITY



Factoids

SCIENCE FACT
Scientists say building a time machine may be impossibly difficult. But time travel is not against the laws of physics.

GAS GUZZLER
One problem for any time-traveler will be the energy bill. Even a small step through time is likely to use up the energy output of a fair-sized star.

BUT SERIOUSLY
Scientists often talk about time travel in the context of its implications for theoretical physics. But they try not to mention "time machines" in case it gets picked up by the supermarket tabloids.

Data TIME TRAVEL TIMELINE

- 1895 BRITISH AUTHOR H.G. WELLS PUBLISHES *The Time Machine*.
- 1905 ALBERT EINSTEIN'S SPECIAL THEORY OF RELATIVITY SHOWS THAT SPACE AND TIME ARE RELATIVE, NOT ABSOLUTE, AND THAT TIME IS ACTUALLY A FOURTH DIMENSION WITHIN WHAT HE CALLS "SPACE-TIME."
- 1916 EINSTEIN DISCOVERS THAT SPACE-TIME IS CURVED.
- 1937 MATHEMATICIAN KURT GOEDEL PROPOSES THAT THE UNIVERSE ITSELF MAY BE A TIME MACHINE.
- 1949 GOEDEL DEMONSTRATES MATHEMATICALLY THAT PATHWAYS THROUGH TIME ARE POSSIBLE.
- 1967 U.S. PHYSICIST JOHN WHEELER INVENTS THE NAME "BLACK HOLE" TO DESCRIBE SINGULARITIES IN SPACE AND TIME.
- 1974 ASTROPHYSICIST FRANK TIPLER PLOTS PATHS AROUND A VAST, IMAGINARY SPINNING CYLINDER, CONFIRMING THAT PATHS THROUGH TIME CAN EXIST.
- 1985 *BACK TO THE FUTURE* (RIGHT) IS RELEASED.
- 1988 CALTECH UNIVERSITY'S KIP THORNE SUGGESTS USING WORMHOLES AS A POSSIBLE MEANS OF TIME TRAVEL.
- 1991 RICHARD GOTT AT PRINCETON UNIVERSITY PROVES THAT COSMIC STRINGS COULD BE USED FOR TIME TRAVEL.



FUTURES

...TOURISTS FROM THE FUTURE COULD VISIT US?

If time machines are possible, it is likely that someone in the future will already have constructed one. After all, in the future there is time to complete even the largest engineering project! Even if humans are not up to the task, creatures from other planets may try. So why are we not overrun by visitors from the future?

This is the argument used by the famous English physicist Stephen Hawking in what he called his "chronology protection conjecture." Like many other scientists, Hawking is troubled by the weird paradoxes of time travel. He argues that the universe simply couldn't allow time travel to happen, because its evolution since the Big Bang cannot be reversed. If the universe were to contract instead of expanding, asks Hawking, would human beings "unevolve" in the same way as they have evolved over millions of years?

A second explanation for the absence of visitors from the future is that none of the time machines envisaged so far lets the voyager go back before the moment the machine was first constructed. So relax. Since no one has built a time machine yet, out-of-time tourists are not a problem!

Technical limitations aside, the "many worlds" theory also solves most of the paradoxes of time travel. According to this

theory, an infinity of universes is constantly being created. In quantum physics, when subatomic particles have a "choice" of options (such as going through one hole or another in a screen), they select one at random. The "many worlds" theory says that there is a universe for each possible choice made by the particle.

"Many worlds" solves another of the famous time travel paradoxes. Say you went back in time and shot your grandfather before he met your grandmother. Would you never have been born? If not, you could never have traveled back in time and shot your grandfather. Which means that you *were* born, so you *could* have gone back... According to "many worlds," when you go back in time you actually emerge in another universe that develops in parallel to our own. But with an infinity of universes to choose from, how can time travelers ever hope to find their way back to the one they started out from?



So far we have managed to avoid being overwhelmed by tourists from the future for good scientific reasons. In fact, time tourism is unlikely to be a problem: Theoretically, time machines have a very limited capacity.

SUPER-SCIENCE, NOT FANTASY

Ever since Einstein, scientists have considered three-dimensional space and time not as two different things, but as different aspects of four-dimensional "space-time." Quantum physicists, who study the world of subatomic particles, often find it easier to explain events by assuming time runs backward as well as forward, however much it defies common sense.

At the other extreme, cosmologists looking at the universe on a grand scale have found that space and time can be warped by gravity and speed. Back in the 1940s, German mathematician Kurt Goedel proved that if we could warp and twist space-time enough—creating what he called "closed, timelike curves"—then we could bore tunnels through time itself. But no one knew how to do the twisting—until black holes.

The gravitational pull of a black hole is so enormous that it distorts the very fabric of space-time into what is called a *singularity*. When singularities were found to spin, it was proved that closed, timelike curves not only can occur—they must occur. The singularity forms a doughnut shape in space-time, while the hole in the middle is a perilous gateway to somewhere—or when.

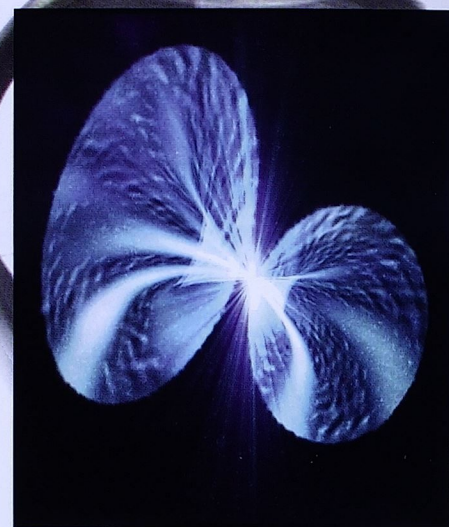
TRUE STORY

Free Lunch

MANY SCIENTISTS ARE UNCOMFORTABLE WITH TIME TRAVEL, NOT BECAUSE IT IS IMPOSSIBLE, BUT BECAUSE OF THE PARADOXES IT CREATES. IMAGINE THAT YOU TRAVELED BACK IN TIME TO VISIT THE COMPOSER LUDWIG VAN BEETHOVEN (RIGHT) AND TOOK WITH YOU A CD OF HIS FIFTH SYMPHONY. BEETHOVEN LISTENS TO IT AND WRITES THE MUSIC DOWN, THEN LATER HIS SCORE IS USED TO RECORD YOUR CD. WHERE DOES THE MUSIC COME FROM? IN SCIENCE, AS IN LIFE, THERE IS NO SUCH THING AS A FREE LUNCH!



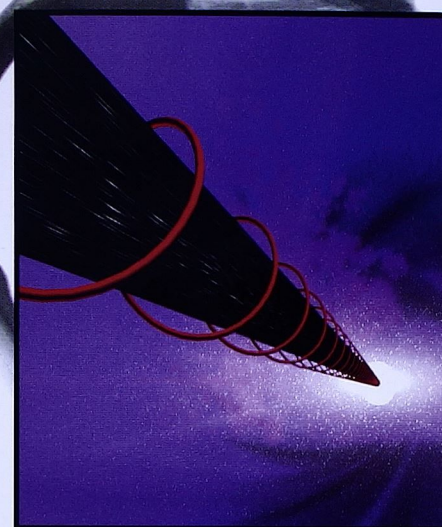
THREE WAYS TO TRAVEL IN TIME WITHOUT BREAKING THE RULES



1 WORMHOLES

Since the 1930s, physicists have speculated about the existence of "wormholes" in the fabric of space. Wormholes are essentially gateways between different parts of the universe and are made by linking a pair of black holes. This effectively creates a tunnel through time and space: A traveler entering at one end would exit the other at a different time as well as a different place.

The difficulty lies in keeping the wormhole open while the traveler makes his journey: If the opening snaps shut, he will never survive to emerge at the other end. For years, scientists believed that the transit was physically impossible. But recent research, especially by the U.S. physicist Kip Thorne, suggests that it could be done using exotic materials capable of withstanding the immense forces involved. Even then, the time machine would be of limited use—for example, you could not return to a time before the wormhole was created. Using wormhole technology would also require a society so technologically advanced that it could master and exploit the energy within black holes. But the trip would not be impossible—just very, very difficult!

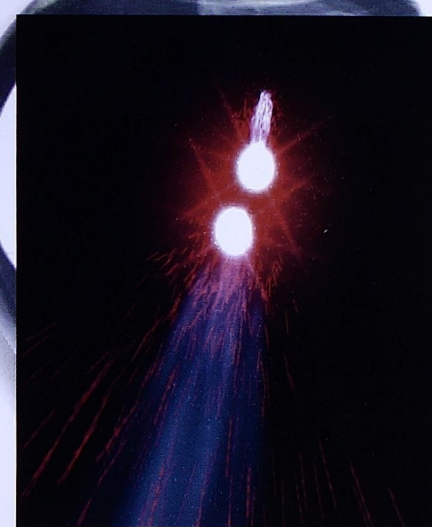


2 ROTATING CYLINDER

Civilizations with the technology to harness black holes might be better advised to leave wormholes alone and try the time-warp method suggested by U.S. astronomer Frank Tipler. He has a simple recipe for a time machine: First take a piece of material 10 times the mass of the Sun, squeeze it together and roll it into a long, thin, super-dense cylinder—a bit like a black hole that has passed through a spaghetti factory. Then spin the cylinder up to a few billion revolutions per minute and see what happens.

Tipler predicts that a ship following a carefully plotted spiral course around the cylinder would immediately find itself on a "closed, timelike curve." It would emerge thousands, even billions, of years from its starting point and possibly several galaxies away.

There are problems, though. For the mathematics to work properly, Tipler's cylinder has to be infinitely long. Also, odd things happen near the ends and you need to steer well clear of them in your timeship. However, if you make the device as long as you can, and stick to paths close to the middle of the cylinder, you should survive the trip!



3 COSMIC STRINGS

As a variation on the rotating cylinder, some scientists have suggested using "cosmic strings" to construct a time machine. At the moment, these are purely theoretical objects that might possibly be left over from the creation of the universe in the Big Bang.

A black hole contains a one-dimensional singularity—an infinitely small point in the space-time continuum. A cosmic string, if such a thing existed, would be a two-dimensional singularity—an infinitely thin line that has even stranger effects on the fabric of space and time.

Although no one has actually found a cosmic string, astronomers have suggested that they may explain strange effects seen in distant galaxies. By maneuvering two cosmic strings close together—or possibly just one string plus a black hole—it is theoretically possible to create a whole array of "closed timelike curves." Your best bet is to fire two infinitely long cosmic strings past each other at very high speeds, then fly your ship around them in a carefully calculated figure eight. In theory, you would be able to emerge anywhere, anytime!

CATEGORY 1 PLANET EARTH

PREDICTING EARTHQUAKES

CLASSIFICATION DISASTER WARNING FROM SPACE



Many of the world's major cities—Los Angeles, Mexico City, Tokyo—are located in earthquake zones. People living there have learned to live with minor tremors. But sooner or later, all of these cities will be hit by a "Big One"—a devastating quake that may claim millions of lives. Seismologists—the scientists whose job it is to predict earthquakes—now face a race against time. In their quest to find a way to give at least some warning, the seismologists are looking to space for help.

SEE ALSO EARTH'S CONTINENTS, VOLCANO WATCH



Factoids

No Chance

There is no chance of running away from an earthquake. The fastest waves, called P waves, roar along at 3 miles per second.

PS...

The P (primary) waves arrive first. The slower S (secondary) waves strike seconds later, shaking down already weakened buildings.

QUAKEPROOF?

When an earthquake hit Mexico City in 1985, it was the so-called "earthquake-proof" buildings that suffered the worst damage by far!

Data MEASURING EARTHQUAKES

There are 2 scales for measuring earthquakes: the Richter and the Mercalli.

For the Richter scale, the magnitude (size) of the waves generated by an earthquake are measured precisely using an instrument called a seismograph. The scale is logarithmic, which means that an earthquake of 3 on the Richter scale is 10 times as big as one of 2. The biggest Richter reading yet recorded was 8.9 from the Chilean earthquake of 1960. The Mercalli scale is used to compare modern earthquakes with those that occurred before the seismograph was invented. The intensity of the quake is estimated according to its effects on a scale of 1–12 in Roman numerals. A Mercalli III quake rattles windows; a Mercalli XII brings total destruction.

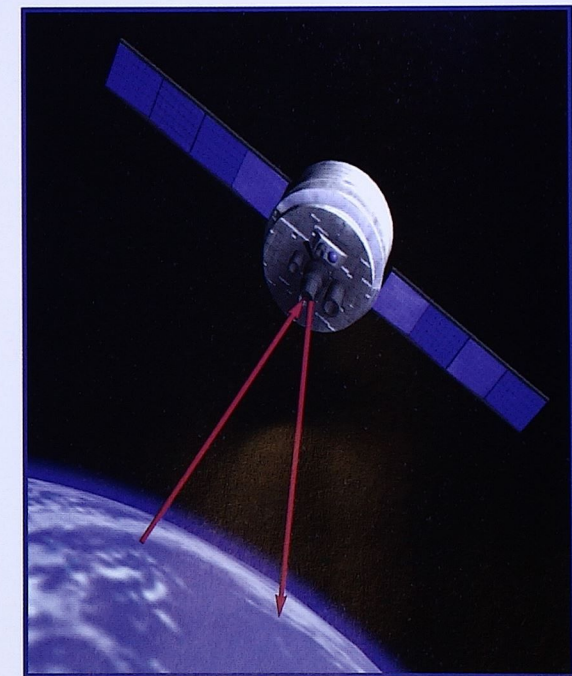
MOST FATAL EARTHQUAKES	DATE	DEATH TOLL
SHANSI, CHINA.....	1556	830,000
CALCUTTA, INDIA	1737	300,000
TANGSHAN, CHINA	1976	255,000
ALEPPO, SYRIA.....	1138	230,000
DAMGHAN, IRAN.....	856	200,000
GANSU, CHINA.....	1920	200,000
XINING, CHINA.....	1927	200,000
ARDABIL, IRAN.....	893	150,000
KWANTO, JAPAN.....	1923	144,000
MESSINA, ITALY.....	1908	100,000

FUTURES

...WE USED SATELLITES TO DETECT GROUND MOVEMENT?

Most seismologists pin their hopes for the future of earthquake prediction on accurate measurement of ground movements using space technology. There are already 45 observatories in more than 30 countries using lasers and satellites to make amazingly accurate measurements—so precise that they can pick up movements of a fraction of an inch over thousands of miles. These systems work by bouncing laser beams off reflectors on satellites orbiting the Earth and measuring how long they take to return.

Toward the end of the century, a linked network of four laser-satellite stations called Keystone will come into operation around Tokyo Bay in Japan. A fifth linked station will be airborne. This linked network will be able to track satellite passes and make measurements in earthquake zones over 700 times a month. The system will provide seismologists with more accurate information about ground movements almost instantly. Armed with this new technology, the scientists hope to be able to map the slight, but telltale, shifts that indicate an earthquake is on its way. It may not be the best answer, but it is better than nothing.



Using laser beams bounced off satellites, it is possible to detect the tiny movements in the Earth's crust that precede a quake. But even if you could predict that an earthquake was about to hit Los Angeles, you would still have the problem of evacuating the city.

...WE COULD LUBRICATE THE CRACKS IN THE EARTH'S CRUST?

Earthquakes are set off by friction between the rock on either side of a fault line. Some people argue that we might be able to reduce the severity of an earthquake by injecting lubricating fluids into the fault so that the rock plates slide past each other more smoothly. This could possibly avert the build-up of tension that results in major quakes. In the past, attempts have been made to lubricate fault lines with water and mud. More recently, it has been suggested that the tension could be reduced by forcing the sides of the cracks apart using high-pressure steam.

QUAKE WATCH

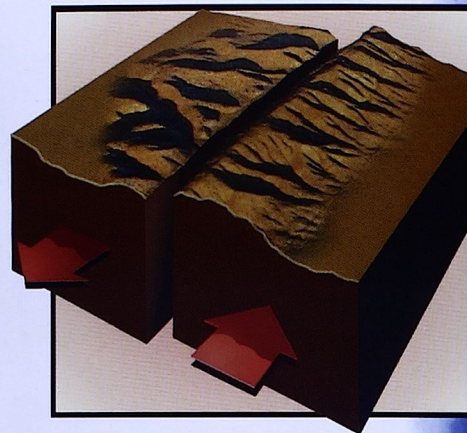
Almost every day, there is an earthquake somewhere in the world. Most of them occur in areas known as *earthquake zones*. Earthquakes happen because the Earth's solid outer crust, or *lithosphere*, is broken into giant fragments called *tectonic plates* that float on the molten rock below. Earthquake zones lie along the cracks between these plates, and earthquakes are triggered by the plates moving past each other. As the plates grind together, the rock on either side of the crack bends, stretches and then snaps. This sudden jolt sends shock, or *seismic*, waves shuddering through the ground to cause earthquakes.

The problem with earthquake prediction is knowing just when the rock is going to snap. In fact, if you live in an earthquake zone and you have not had an earthquake for some time, expect one soon. The longer the time since the last quake, the bigger the next quake will be. This is because there has been more time for the strain in the rocks to build up. Big quakes might occur every century or so, smaller ones every few decades.

Scientists now get help from space in making high-precision surveys that monitor the risk areas for signs of slight horizontal and vertical movement. The margin for error is still wide, but even a slight increase in accuracy could one day save millions of lives.

TRUE STORY Dogs Do Bark!

IT HAS LONG BEEN BELIEVED THAT MANY ANIMALS ARE SENSITIVE TO IMPENDING EARTHQUAKES. LONG BEFORE ANY TREMORS ARE DETECTED ON THE MOST SENSITIVE EQUIPMENT, DOGS ARE SAID TO HOWL, PANDAS MOAN, CHICKENS FLEE ROOSTS, RATS AND MICE SCAMPER FROM THEIR HOLES AND FISH THRASH ABOUT IN PONDS. THESE PHENOMENA ARE SO WIDELY REPORTED THAT SEISMOLOGISTS NO LONGER DISMISS THEM AS MYTHS: CURRENTLY THEY ARE STUDYING ANIMALS TO SEE IF THEY PICK UP ON SOME INDICATOR THAT MAY ONE DAY HELP US PREDICT EARTHQUAKES.



Earthquakes occur where tectonic plates rub against each other (left). This sends tremors through the Earth's crust that are powerful enough to flatten cities.

UNDER STRESS

One sign of tectonic plates on the move may be changes in ground water levels, because the stress in the rock squeezes the water upward. A group of Chinese seismologists claim success with predictions based on water levels in wells and boreholes. Another sign may be increased levels of radon gas in the ground, forced upward by built-up pressure. Changes in the electrical resistance of the ground, or in its magnetism, may also hold clues.



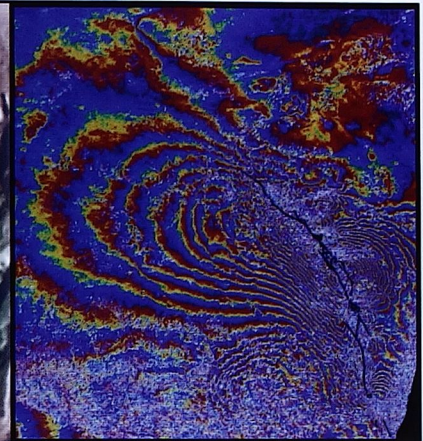
The pyramid-shaped TransAmerica building in San Francisco (left) is designed to be earthquake-proof. Even so, it cannot be put to the test until the Bay Area is hit by a major quake.

BUILT TO LAST

Most deaths in earthquakes are caused by collapsing buildings and roadways. So in earthquake-prone San Francisco and in many Japanese cities, all new buildings must be built to particular safety guidelines. Ideas on the best construction for earthquake resistance differ, but regulations insist on deep, firm foundations of steel and concrete. Wide-based pyramid structures are also encouraged. But even such buildings do not come with a guarantee.

CALIFORNIA EARTHQUAKE ZONE

Right: a space radar image of ground changes following the quake at Landers, California, on June 28, 1992. It measured 7.3 on the Richter Scale.



EARTH MOVEMENT

On average, plates slip past each other an inch or so a year. In a slip that triggers a major quake, the plates may move a few yards or more. A major earthquake can easily lift an entire mountain yards in the air. Shallow earthquakes originate 0-40 miles below ground. These are the ones that do the most damage. Intermediate earthquakes originate 40-180 miles below ground. Deep ones originate below 180 miles down. The deepest recorded quake started 450 miles down.



The San Andreas Fault is at its most spectacular where it runs across the Carrizo Plain (right), 300 miles south of San Francisco.

hard evidence

MONITORING THE FAULT

ALONG CALIFORNIA'S SAN ANDREAS FAULT, TWO GIANT TECTONIC PLATES ARE SLIPPING PAST EACH OTHER. SINCE THE GREAT SAN FRANCISCO EARTHQUAKE OF 1906, MOVEMENT ALONG THIS FAULT HAS BEEN MONITORED. SOME SECTIONS SHOW ALMOST CONTINUOUS MICROEARTHQUAKES, WHICH RELEASE TENSION. OTHER SECTIONS, SEISMIC GAPS, SHOW NO SIGNS OF ACTIVITY. THIS IS WHERE THE BIG ONE WILL OCCUR, AS THE PRESSURE BUILDS UP TO A POINT WHERE IT CAN ONLY BE RELEASED BY A MASSIVE SHIFT. BUT WHEN?



HIDDEN FAULT

The worst earthquake disaster to hit America in recent years was the deadly quake that struck without warning in the Los Angeles suburb of Northridge on January 19, 1994. In just 30 seconds of total mayhem, 11,000 homes were destroyed, dozens of freeways reduced to rubble and scores of people killed or injured. Yet before the fatal disaster, no one knew of the existence of the branch of the fault line whose suddenly shifting tectonic plates triggered the devastation.

CATEGORY 6 THE NIGHT SKY

USING A TELESCOPE

CLASSIFICATION FINDING OBJECTS IN THE SKY



A new telescope... a crystal-clear sky... what more could the amateur astronomer want? But often the outcome is frustration when it proves difficult to find stars, planets or other astral objects in the lens. Fortunately, there are tips from experienced observers that can help you get the most out of any telescope, or even binoculars. With practice, it will only take moments to find many of the wonders of the sky—even those too small or faint to be visible at first glance.

SEE ALSO REFLECTING TELESCOPES, STARGAZING SOFTWARE

CARD
17

Factoids

SIDE GLANCE

When searching for a faint object, look slightly to one side of where you expect it to be—it may suddenly become visible. This works because the edge of your vision is more sensitive to light than the center.

TURN UP

Remember that most astro telescopes give an upside-down image compared with the naked-eye view.

NO SPECS

If you wear glasses, you do not normally need them when looking through a telescope. Only people diagnosed with a bad astigmatism may need to use their glasses.

Data OBJECTS TO PRACTICE ON

The following objects are particularly rewarding if you have just bought a telescope:

NAME	TYPE OF OBJECT	RIGHT ASCENSION	DECLINATION	BEST MAGNIFICATION
EARTH'S MOON	MOON	VARIES	VARIES	50x TO 350x
JUPITER	PLANET	VARIES	VARIES	50x TO 200x
M 4	GLOBULAR CLUSTER	16hr 24min	-26°32'	75x
M 31, ANDROMEDA GALAXY	SPIRAL GALAXY	00hr 43min	+41°16'	25x TO 50x
M 42, ORION NEBULA	BRIGHT NEBULA	00hr 35min	-05°30'	25x TO 50x
M 45, PLEIADES	OPEN CLUSTER	03hr 47min	+24°07'	15x TO 25x
M 57, RING NEBULA	PLANETARY NEBULA	18hr 54min	+33°02'	150x

FUTURES

...YOU COULD DIAL UP A STAR?

The positions of objects in the sky are pinpointed using the sky's equivalent of longitude and latitude, called *right ascension* and *declination*. Equatorial-type telescope mountings have dials, called setting circles, that carry these scales. So why isn't it easy to find an object in the sky simply by dialing up its position? It is—but only with the aid of a computer.

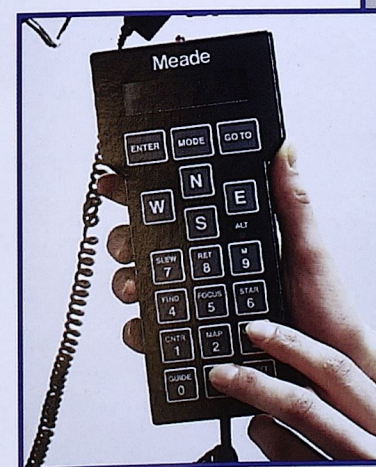
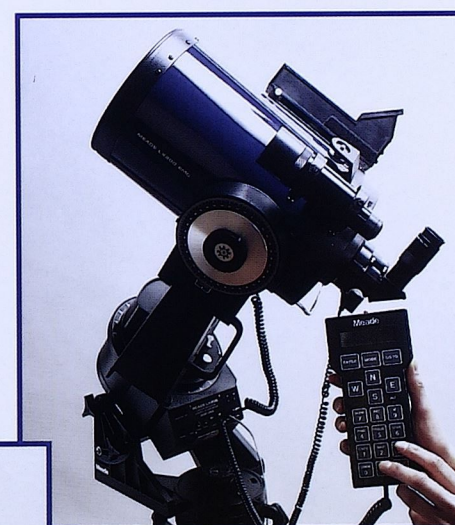
Part of the problem is that because of the Earth's daily rotation, the direction of a given right ascension is changing all the time. Similarly, the direction of a given declination depends

on the location of the telescope on Earth. Before an equatorial mounting can be used, it must be aligned so that one axis is exactly parallel with the Earth's axis, which takes time and care. Then its setting circles must be set up for the particular time of the observation.

This procedure has to be repeated each time you set up the telescope, so many people with portable instruments prefer to find objects by star-hopping. But now there are computer-controlled mountings which do away with all the fiddling. These mountings have optical encoders on their axes, which give a digital readout of which direction the telescope is pointing. They are also equipped with purpose-built computerized handsets that are pre-programmed with the positions of thousands of celestial objects.

To find an object, all the user has to do is to be able to recognize two bright stars in the sky. The

telescope is pointed toward each one in turn, and the identity of the star is entered on the handset. Since any two stars are in unique directions at a given time and place on Earth, the computer can then work out the position of any other object in the sky, and will move the telescope to it on command. To find a planet, you have to key in the date as well. A computerized mounting does not even need to be aligned with the Earth's axis. It will track a chosen object even if it is not equatorially mounted, although this is still necessary for taking long-exposure photographs.



Computer-controlled telescopes use a simple handset, such as the one shown above and left, for all data input. They can also be hooked up to a computer running a sky mapping program for even greater flexibility.

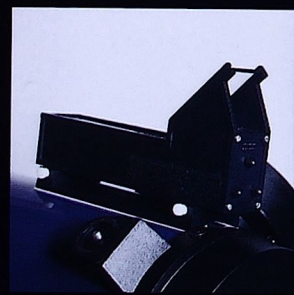
STAR GAZING

The main reason why people find it hard to locate objects through a telescope is that it shows only a tiny part of the sky at a time. A telescope may show many stars in an area where few are visible with the naked eye. But which star is which?

This is where the finder telescope that is attached to the tube of the main instrument comes in handy. To start with, choose the lowest magnification available on your main telescope and find an easy-to-locate object, such as the Moon. Then adjust the screws holding the finder so that it is centered on exactly what you can see with the main telescope.

Practice finding other easy objects, such as bright stars or planets, by getting them dead center in the finder, then looking through the main telescope, still using its lowest magnification. Then progress to fainter stars until you are familiar with the extra stars visible, and with their increased brilliance in the telescope. Compare what you see with the finder with the view in the main telescope. After practicing for a while, try increasing the magnification where necessary.

Low magnifications (around 50) are best for many nebulae and clusters, while higher powers (100 to 200) are suited to planets, many galaxies and *planetary nebulae*—shells of gas from dying stars. The highest powers (250 or more) are generally only useful when looking at the Moon or at planets on nights when atmosphere is at its steadiest.



Hot Tip Bullseye Finder

MANY OBSERVERS USE NON-MAGNIFYING FINDERS TO HELP LOCATE OBJECTS. ALIGNED WITH THE MAIN TUBE OF THE TELESCOPE, THEY PROJECT AN ILLUMINATED BULLSEYE ON THE SKY WHEN YOU LOOK THROUGH THEM. THIS HELPS YOU FIND ANY OBJECT WHOSE POSITION IN THE SKY YOU KNOW, AND IS MUCH EASIER THAN TRYING TO SQUINT ALONG THE TUBE OF THE MAIN TELESCOPE.

THROUGH A GLASS...

NAKED EYE

To find the Wild Duck Cluster in the August sky, first locate this C-shape of stars on the borders of Aquila and Scutum.

X6 POWER BINOCULARS

Through the finder, the cluster itself appears as a small, fuzzy blob to one side of the C-shape.

NAKED EYE

Jupiter is one of the brightest objects in the night sky, with a pale cream color. It was in this position in 1996.

X6 POWER BINOCULARS

Jupiter still appears as a bright star, but one or two of its moons may be visible close to it.

X100 POWER TELESCOPE

Through the main telescope, with a magnification power of about 100, individual stars are visible in the cluster—also known as M 11.

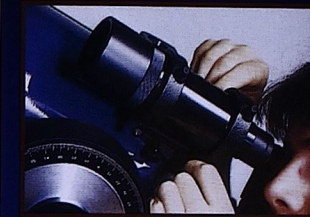
X100 POWER TELESCOPE

Jupiter becomes a solid body, with belts and zones and up to four of its brightest moons visible, depending on their orbital positions.

Hot Tip

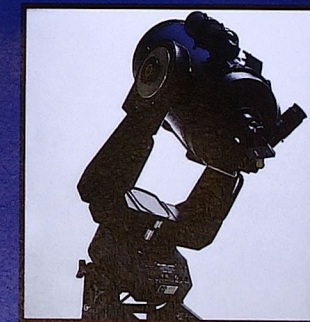
ADJUST THE FINDER

USE THE SCREW ADJUSTERS ON THE FINDER TO MAKE SURE THAT IT IS EXACTLY CENTERED ON THE OBJECT IN THE MAIN TELESCOPE.



TRACK IT

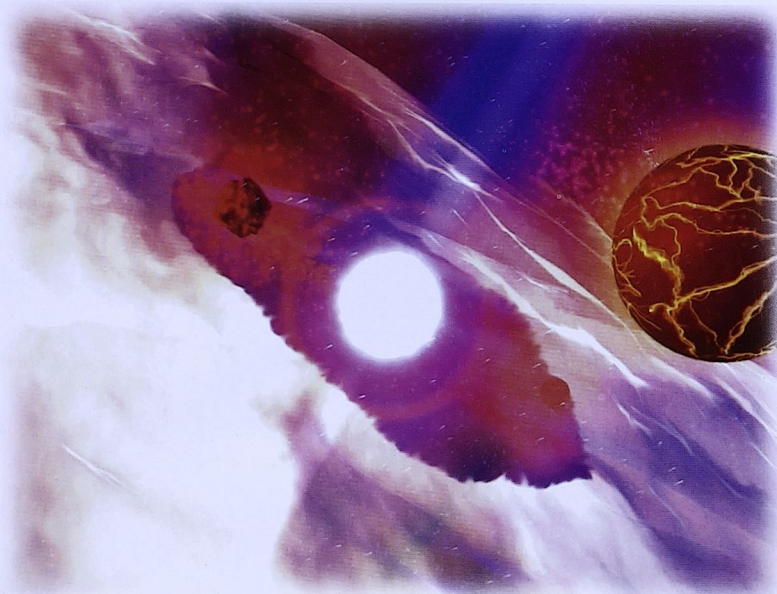
EQUATORIAL-TYPE TELESCOPE MOUNTS (BELOW) HAVE ONE AXIS AT AN ANGLE. POINT THIS AXIS DUE NORTH AT THE SAME ANGLE AS YOUR OWN LATITUDE AND IT WILL BE ALIGNED WITH THE EARTH'S OWN AXIS. NOW YOU CAN TRACK OBJECTS AS THEY MOVE, EITHER BY TURNING JUST ONE OF THE SLOW-MOTION CONTROLS, OR BY SWITCHING ON THE MOTOR TO COUNTERACT THE ROTATION OF THE EARTH.



Star-hopping

Find faint objects using the "star-hopping" method. With a star map, find a star that you can locate in the finder. Look around it for easily recognized patterns of stars, such as triangles and straight lines. Then use your experience of comparing the views in the finder and the main instrument to hop from star to star until the object you are seeking is in the center of the field of view. Begin with a low magnification, and only increase the power with care, to avoid losing the object as you refocus the telescope.

THE SOLAR SYSTEM



Our solar system began life as a great cloud of gas and dust which, around 5 billion years ago, began to collapse in on itself under the force of its own gravity. As the cloud shrank, it started to spin and flatten out into a disk. Eventually, the center began to heat up as the particles of gas and dust smashed into each other, forming the star we know as our Sun. The rest of the material went on to form the planets, moons, asteroids, comets and other debris that make up the solar system.

SEE ALSO THE SUN, PLANETARY ORBITS, ASTEROID BELT



Factoids

BACKWARD SPIN

Relative to the other planets in the solar system, Venus spins backward on its axis. Early on, when the planets were forming, Venus may have been hit by a massive object that reversed its spin.

LEFTOVERS

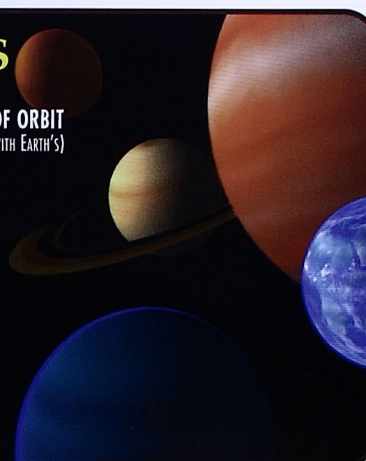
Far into space, beyond the orbit of Pluto, is a giant cloud of frozen comets—leftovers from the formation of our solar system.

NEARLY A STAR

If Jupiter had been just a fraction bigger than it is, it would have turned into a star and our solar system would have had two Suns instead of one.

Data SOLAR ORBITS

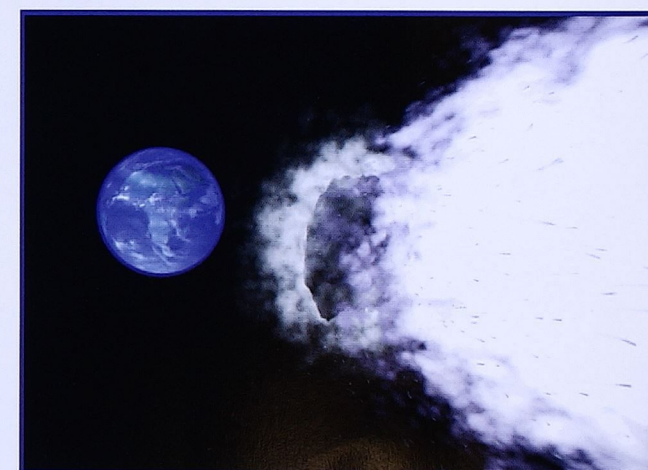
PLANET	DISTANCE FROM SUN (MILLION MILES)	DIAMETER (MILES)	MASS (EARTH = 1)	MEAN DENSITY (COMPARED WITH WATER)	ANGLE OF ORBIT (COMPARED WITH EARTH'S)
MERCURY	35.98	3,030	0.055	5.43	7.004°
VENUS	67.23	7,520	0.82	5.25	3.394°
EARTH	92.96	7,926	1	5.52	0°
MARS	141.6	4,217	0.11	3.95	1.850°
JUPITER	483.6	88,846	317.94	1.33	1.308°
SATURN	886.7	74,898	95.18	0.69	2.488°
URANUS	1,784	31,763	14.53	1.29	0.774°
NEPTUNE	2,794	30,775	17.14	1.64	1.774°
PLUTO	3,675	1,419	0.002	2.03	17.148°



FUTURES

...OUR SOLAR SYSTEM HIT ANOTHER STAR?

As the solar system passes through the Milky Way galaxy, of which it is a part, there is a theoretical possibility that it could be "disturbed" by the gravitational field of a nearby star system. This would in turn affect the orbits of many of the vast number of cold comets that orbit the Sun way beyond the outer planets. Astronomers predict that such a disturbance would send millions of comets hurtling into the inner regions of the solar system—it would, literally, start raining comets, some of which would be bound to hit the Earth. A direct hit by a large comet would be disastrous, and could result in the extinction of all life on the planet.



If our solar system strayed too close to another star, the resulting gravitational pull could disrupt the cloud of frozen comets that orbit beyond Pluto and send them crashing toward Earth.

...THE SUN GROWS COLD?

Far into the future, the Sun will use up all the hydrogen gas that powers its nuclear reactor. At that point it will start burning the helium created as a by-product of earlier reactions, and will swell up to become a red giant star.

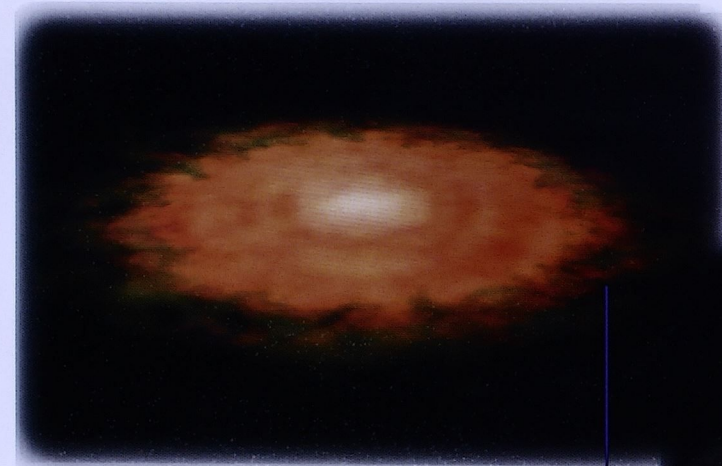
When the Sun becomes a red giant, it will extend out as far as the orbit of Venus, or possibly even the Earth. All of the inner planets—Mercury, Venus, Earth and Mars—will be engulfed, but not destroyed. Uninhabitable, due to their massively high surface temperatures, they will live on inside the Sun's fiery orb. By then, hopefully, the human race will have moved farther out into the solar system—possibly to

one of the moons orbiting the outer planets, whose gassy atmospheres will long since have been boiled away by the red giant Sun.

When all of the helium in the Sun is used up, it will collapse in on itself in a violent explosion that will blow the outer layers far into space. If humans are still around then, they had better keep their heads down: The debris will blast through the solar system and into deep space, where it will help to form new solar systems—and, possibly, new life.

But don't worry: Astronomers have worked out that the Sun is only halfway through its natural life. We still have another 5 billion years to go before we have to check out of planet Earth and abandon the solar system we now call home.

THE CONDENSING CLOUD



1 COLLAPSING CLOUD

Our solar system started as a vast cloud of gas and dust. Due to the effect of its own gravity, the cloud collapsed, began to spin, and formed itself into a disk shape. As this happened, the cloud began to heat up, especially at the center.

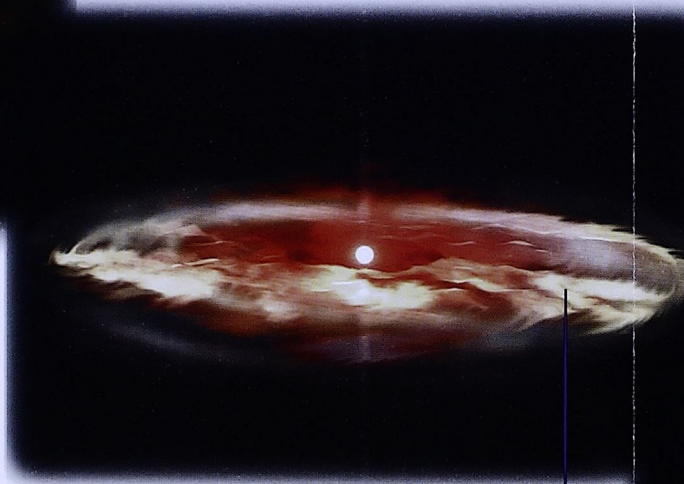
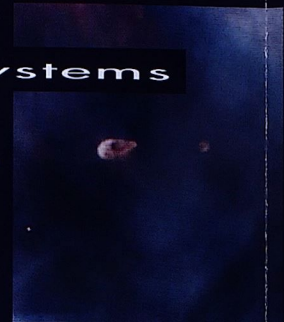
Even a quick glance at the structure of our solar system raises some intriguing questions. For example, why are the inner planets—Mercury, Venus, the Earth and Mars—small and rocky with relatively thin atmospheres, while the outer planets—Jupiter, Saturn, Uranus and Neptune (icy Pluto being an exception)—are much larger, with thick, dense atmospheres? The answer gives us an insight into how the solar system formed.

In the beginning there was a vast, swirling cloud of gas and dust. The gas was largely hydrogen, along with some helium; the dust was made up of small amounts of various ices, oxides, carbon and some heavier elements such as iron. Most of the hydrogen and helium were created at the beginning of the universe. The other material originated inside an earlier generation of stars that exploded in supernovae at the end of their lives.

TRUE STORY

New Systems

DEEP IN THE HEART OF THE ORION NEBULA (M 42), YOUNG STARS ARE SHINING AND NEW ONES ARE FORMING. AROUND SOME OF THE OBJECTS IN THIS STELLAR NURSERY, THE HUBBLE SPACE TELESCOPE HAS DETECTED DISKS OF MATTER—EVIDENCE, PERHAPS, OF NEW SOLAR SYSTEMS FORMING. ASTRONOMERS CALL SUCH STARS AND THEIR ORBITING MATTER *PROPLYDS* (ABOVE). M 42 IS FAINTLY VISIBLE TO THE NAKED EYE AS A SMUDGE OF WHITE IN THE SWORD OF THE HUNTER'S FIGURE IN THE CONSTELLATION ORION.



2 HOT AND COLD

Eventually the temperature and pressure rose high enough to start a nuclear reaction, and the Sun began to shine. The remaining matter vaporized, then condensed into tiny particles, leaving the heavier elements close to the Sun and the lighter materials, such as ice, farther out.

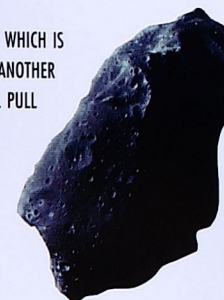
Around 4.56 billion years ago, under the force of its own mounting gravitational pull, the cloud began to collapse and start spinning, causing it to flatten into a disk shape. The compression accompanying the collapse caused the cloud to heat up. In the center, the heat and pressure became so great that nuclear reactions started, signaling the birth of the Sun.

hard evidence



STILLBORN PLANET

THERE IS ENOUGH ROCKY DEBRIS (RIGHT) IN THE ASTEROID BELT, WHICH IS SITUATED BETWEEN THE ORBITS OF MARS AND JUPITER, TO MAKE ANOTHER PLANET ABOUT HALF THE SIZE OF OUR MOON. THE GRAVITATIONAL PULL OF JUPITER, HOWEVER, PREVENTED SUCH A PLANET FROM EVER FORMING. SMALL PIECES FROM THE ASTEROID BELT CALLED METEORITES (LEFT) BREAK AWAY AND OFTEN FALL TO EARTH, GIVING SCIENTISTS VALUABLE CLUES TO THE ORIGIN OF OUR SOLAR SYSTEM.



Collecting Together

Around the Sun, the dust was vaporized. Less volatile (harder to vaporize) elements such as iron and silicon condensed again relatively close to the Sun to form solid particles. Farther out in space, the more volatile matter condensed to form ice.

The particles of solid matter gradually collected together into larger lumps, eventually forming so-called *planetesimals*—tiny planets up to 6 miles across. This early formation period was one of great violence. As the planetesimals whirled around the young Sun, they smashed into each other. Then, after each collision, the fragments reformed under their own mutual gravitational attraction to form

much larger bodies called *planetoids*. The planetoids, in turn, came together to form the planets as we know them today. Close to the Sun the planetesimals were of a dense and essentially rocky material like the Earth. Farther out, much icier planetesimals collected together to form the outer planets.

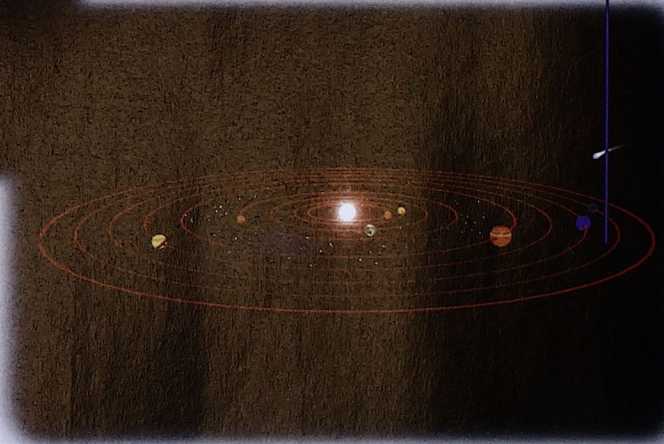
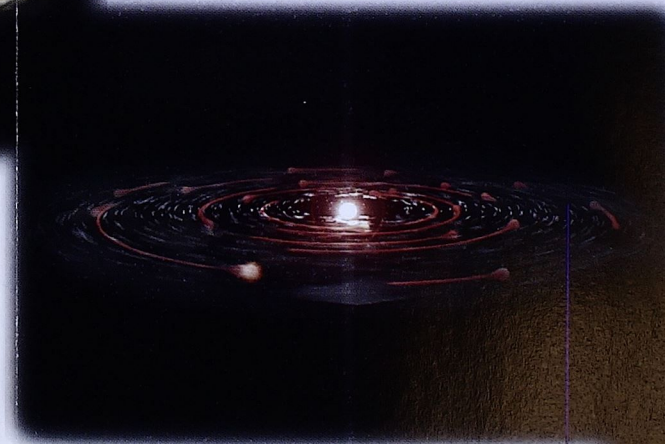
The outer planets grew to be larger than the inner planets because their icy components were more plentiful than the heavier materials in the original cloud. When these planets grew massive enough, they attracted the remaining hydrogen and helium from the disk surrounding the new Sun. This made them bigger still, and accounts for their thick, dense atmospheres.

4 COMPLETE SYSTEM

Most of the matter in the solar system today is tied up in the Sun, the planets, and their moons. But the rocky asteroids in the Asteroid Belt and the icy comets that orbit out in deep space are still there to remind us what the early solar system was like.

3 BUILDING BLOCKS

The particles began to collect together, smashing into each other and reforming as bigger and bigger bodies each time. Eventually these bodies formed into planets. The spinning disk ensured that their orbits around the Sun remained more or less on the same plane.



CATEGORY 2 THE SOLAR SYSTEM

THE MOON

CLASSIFICATION EARTH'S NEAREST NEIGHBOR



The Moon is the most familiar sight in the night sky. This is because it is the Earth's closest companion and travels with the Earth in space around the Sun. The Moon orbits the Earth at a distance of just 238,850 miles; yet, despite being so near, it is very different from our own planet—a gray desert, dotted with craters from ancient asteroid collisions. So far the Moon is the only body in space on which humans have landed. The recent discovery of water there has stimulated plans for an eventual return.

SEE ALSO PHASES OF THE MOON, OBSERVING THE MOON



Factoids

LIGHTWEIGHT

Because it is far smaller and lighter than the Earth, the Moon also has less gravitational pull. As a result, on the Moon you would weigh just one-sixth of your body weight on Earth.

SILVERY MOON

The Moon appears dark gray because its surface reflects only 12% of the sunlight that hits it.

TIME FLIES

The Moon is slowly spiraling away from us at a rate of 1½ in a year. One billion years ago, when the Moon was closer, a lunar month lasted only 6½ hr.

Data MOON FACTS & FIGURES



DIAMETER	2,160 MILES
AXIS TILT	6° 41' RELATIVE TO ITS ORBIT
TIME TO ORBIT EARTH	27.3 EARTH DAYS
LENGTH OF DAY	27.3 EARTH DAYS
DISTANCE FROM EARTH	238,850 MILES
SURFACE TEMPERATURE	253°F (DAY) TO -387°F (NIGHT)
SURFACE GRAVITY	0.17 OF THE EARTH'S
MASS	0.012 OF THE EARTH'S
VOLUME	0.02 OF THE EARTH'S
DENSITY	3.34 TIMES THAT OF WATER

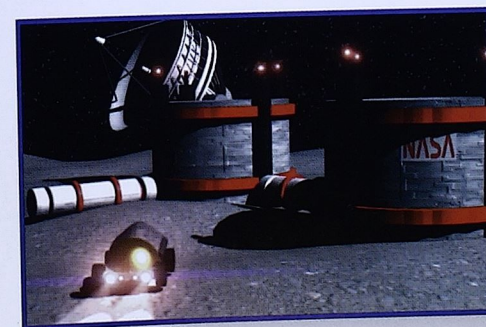
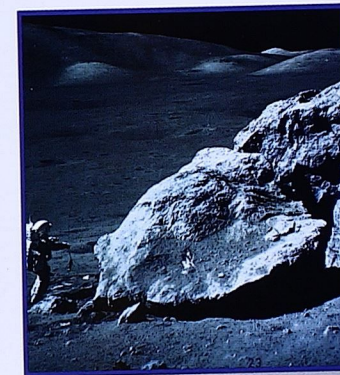


FUTURES What if...

...WE RETURNED TO THE MOON?

Twelve American astronauts landed on the Moon between 1969 and 1972 during the Apollo program. No one has been back since, although NASA plans to send astronauts back to the satellite before the year 2020. NASA Administrator Daniel Goldin has also outlined plans for a Mars mission that may be launched from the Moon. Analysis of the rocks brought back by the Apollo astronauts show that the Moon contains useful amounts of metals, such as aluminum, iron, titanium and magnesium, which could be used to build spacecraft. And since the Moon's gravity is weaker than the Earth's, launching rockets from there would be far easier.

Returning to the Moon could be the first stage of an expedition to Mars (right).



Plans for building a Moon base are already well advanced, though no date has been set. Ultimately, there will be mining colonies on the surface supplying Earth with minerals (above).

...WE ESTABLISHED A MOON BASE?

The discovery of water ice at the Moon's poles has stimulated plans to set up bases using pressurized cylinders, like those used in present-day space stations. The cylinders will be covered with lunar soil to protect them from cosmic rays and meteorites.

At first, scientists will use the bases to explore the mountains, craters and valleys of the Moon to find out more about its history. Observatories will be established to obtain a clearer view of the sky than is possible from Earth, where our atmosphere gets in the way. It will also be desirable to set up radio telescopes, to study the cosmos free of interference from radio transmissions on Earth.

Energy to power the lunar bases will come from sunlight. Solar power will also be used to convert the water ice at the poles into hydrogen and oxygen for fuel; oxygen for breathing will be extracted from the deposits currently "locked away" as oxides in the Moon's rocks. The same rocks could be used to extend the bases. Plants for food will be grown in Moon soil, with added water and fertilizer; farm animals and fish will be kept in pressurized domes.

Eventually, we will mine the Moon for the valuable minerals that it contains. Instead of rockets, magnetic ramps called mass drivers may be used to propel containers of Moon rocks into space. The rocks will then be ferried to Earth or processed in space factories. One day it may also be possible for tourists to take vacations on the Moon, living in lunar hotels and visiting sites such as Tranquillity Base, where the first Apollo astronauts landed in 1969.

MOONSCAPE

Since the Moon is so close, we can see its most prominent features with the naked eye. Most obvious are the dark areas that form the familiar "Man-in-the-Moon" pattern. In reality these are lowlands, formed by giant meteorites that smashed into the Moon long ago, which were then filled by dark lava. They are called *maria*, a Latin word meaning "seas" (singular: *mare*); although there has never been any water in them, that is what they looked like to early observers. Many of the maria are given fanciful names, such as Mare Tranquillitatis (Sea of Tranquillity) where Apollo 11 astronauts landed in 1969. The bright areas on the Moon are rugged highlands.

The rugged, colorless appearance of the Moon is in stark contrast to the surface of the Earth. There is no air on the Moon, so there are no clouds to spoil our view. A look through a pair of binoculars reveals that the Moon is pitted with craters, the largest of which can engulf a fair-sized city. These, too, were formed long ago by meteorite impacts. Some of the craters are bordered by bright streaks, called *rays*, which consist of crushed rock thrown out by the crater-forming impacts. Lunar craters are named after famous people, mostly astronomers. The most notable example is Tycho, in the Moon's southern hemisphere, where the formation is particularly noticeable around the time of a full moon.

MARIA

The darker areas of the Moon's surface. They are depressions created by the impact of giant meteorites which were filled with dark lava when the Moon experienced volcanic activity.



HIGHLANDS

The bright areas on the Moon are craggy highlands, whose light rocks reflect the sunlight. This contrasts with the dark, sunlight-absorbing rock in the lava-filled maria.



ANATOMY OF OUR MOON

TRUE STORY

Double Planet

OUR MOON IS LARGER THAN ANY OTHER MOON IN THE SOLAR SYSTEM IN RELATION TO ITS PARENT PLANET EXCEPT THAT OF PLUTO. SEEN FROM SPACE, THE EARTH AND MOON LOOK MORE LIKE A DOUBLE PLANET EVEN THOUGH THEIR COMPOSITIONS ARE IN FACT VERY DIFFERENT. THE MOON IS LESS DENSE, AND DOES NOT HAVE A MOLTEN IRON CORE.



Birth of the Moon

Astronomers believe that the Moon was born about 4.6 billion years ago when the youthful Earth was hit by another body, larger than the present Moon. The colliding body shattered completely under the force of the impact, which also melted part of the Earth's outer layers. The debris from the collision then went into orbit around the Earth, where it collected together to form the Moon. The lack of air and liquid water means that there is no erosion, with the result that the Moon's surface features have remained virtually unchanged for millions of years.

Whenever we look at the Moon, we always see the same side. This is because the Moon turns on its axis in exactly the same time (27.3 days) that it takes to orbit Earth—a phenomenon known as "synchronous rotation." Until space probes orbited the Moon, no one knew what the far side looked like. The first probe to

TRUE STORY

Far Horizons

BECAUSE THE MOON IS ONLY ONE-QUARTER THE SIZE OF THE EARTH, ITS SURFACE IS MORE NOTICEABLY CURVED. THIS ALSO MEANS THAT THE MOON'S HORIZON IS MUCH CLOSER—SO MUCH SO THAT IF YOU WERE STANDING INSIDE A LARGE CRATER ON THE MOON, YOU WOULD BE UNABLE TO SEE THE SURROUNDING WALLS BECAUSE THEY WOULD BE BELOW THE HORIZON!



photograph the Moon's far side was Russia's Luna 3 in October 1959; since then, it has been fully mapped. The main difference is that the far side is mostly covered with bright, crater-marked highlands, and has fewer large, dark mare areas.

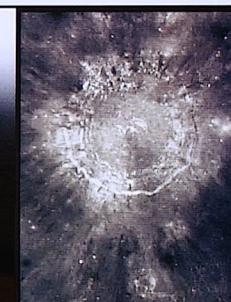
CRATERS

The surface of the Moon is pitted with craters, the largest of which can engulf a city. They, too, were formed long ago by meteorite impacts. Some craters at the poles never receive sunlight, and in 1998 were found to contain traces of water ice.



RAYs

Some craters are surrounded by bright streaks called *rays*. These consist of crushed rock thrown out of the crater at the time of impact.



MOON DUST

The Moon is covered in very fine dust called *regolith*. It is made from rock pulverized by eons of meteor impacts. Some pieces of rock are shaped like droplets, where the rock has been melted and splashed across the surface.

